2A94-28

A SYNOPSIS AND CRITIQUE OF FORECASTS OF SOCKEYE SALMON RETURNING TO BRISTOL BAY IN 1994

by

Beverly A. Cross

REGIONAL INFORMATION REPORT[1] NO. 2A94-28

Alaska Department of Fish and Game
Division of Commercial Fisheries Management and Development
333 Raspberry Road
Anchorage, Alaska 99518

September 1994

[1] The Regional Information Report Series was established in 1987 to provide an information access system for all unpublished divisional reports. These reports frequently serve diverse ad hoc informational purposes or archive basic uninterpreted data. To accommodate timely reporting of recently collected information, reports in this series undergo only limited internal review and may contain preliminary data; this information may be subsequently finalized and published in the formal literature. Consequently, these reports should not be cited without approval of the author or the Division of Commercial Fisheries Management and Development.

AUTHORS

Beverly A. Cross is Region II Bristol Bay Research Project Leader for the Alaska Department of Fish and Game, Division of Commercial Fisheries Management and Development, 333 Raspberry Road, Anchorage, AK 99518.

ACKNOWLEDGMENTS

Stephen Fried, Regional Research Biologist, and Linda Brannian, Regional Biometrician, provided analytical and statistical guidance throughout the analyses. The entire Bristol Bay full-time and seasonal staff of the Commercial Fisheries Management and Development Division, ADF&G, assisted in collecting data upon which 1994 predictions were based. We would like to thank Tom Brookover (Togiak Management Biologist), Jeffrey Regnart (Naknek-Kvichak Management Biologist), Richard Russell (Egegik/Ugashik Management Biologist), Jeffrey Skrade (Nushagak Management Biologist), and Barry Stratton (Fishery Biologist, Sport Fish Division) for their helpful discussions and constructive suggestions.

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS(Continued)

LIST OF TABLES

LIST OF FIGURES

LIST OF FIGURES (Continued)

LIST OF APPENDICES

LIST OF APPENDICES (Continued)

ABSTRACT

The total number of sockeye salmon *Oncorhynchus nerka* forecasted to return to Bristol Bay in 1994 is 55,991,000 (80% confidence interval: 41,308,000 - 70,674,000). Runs are expected to exceed spawning escapement goals for all systems. Total projected sockeye salmon harvest is expected to be 43,206,000. Most of this harvest will be taken within Bristol Bay inshore fishing districts (39,620,000), but some have been allocated to June fisheries occurring in the vicinity of the Shumagin Islands and South Unimak under an existing management plan (8.3% of total Bristol Bay projected harvest= 3,586,000). The 1994 forecast was based on the ADF&G method which averaged results from three linear regression models based on the relationship between returns and either spawner, sibling, or smolt data. Based on performance evaluations of the ADF&G method, all available data was used to forecast 1994 runs to Nushagak and Togiak Districts, but data prior to the 1978 return year were omitted from calculations for Naknek-Kvichak, Egegik and Ugashik Districts. To further correct under-forecasting errors, predictions for all rivers, except Nushagak River, were adjusted by the 1984-93 average percent forecast error of the corresponding systems. Similar to last year, out of range data were used in calculations for the 1994 forecast. The number of spawners in 1990, the number of age-2 smolt outmigrating in 1991, and the number of age-2.2 returns in 1993 were greater than previously recorded for Egegik River. Because these data are greater than those included in the regression models, we have less confidence in the accuracy of the prediction for Egegik River. The outlook for 1994-97, based only on the spawner-recruit component of the forecast and not adjusted for average historic forecast errors, is for the total sockeye salmon run to Bristol Bay to be similar from 1994 to 1997. For all years examined, runs to all river systems are expected to exceed spawning goal requirements.

KEY WORDS: Salmon forecast, sockeye salmon, *Oncorhynchus nerka*, Bristol Bay, spawner-recruit, environmental indicators

INTRODUCTION

Preseason forecasts of sockeye salmon *Oncorhynchus nerka* runs to Bristol Bay, Alaska, have been made by the Alaska Department of Fish and Game (ADF&G) since 1961 (ADF&G 1961; Appendix A.1). ADF&G biologists use forecasts to (1) estimate commercial harvests, (2) set quotas for the Shumagin Islands-South Unimak June fishery (ADF&G 1992), and (3) determine which stocks may need protection against possible overharvesting. Seafood buyers and processors use forecasts to (1) estimate the supply of raw fish available for various uses, (2) determine staff and equipment needed for production of fresh, frozen, and canned products, and (3) plan deployment of tenders and processing vessels. Commercial fishermen use forecasts to decide which areas might provide them with the best fishing opportunities and to assist in decisions involving future investments for equipment.

Until 1983, annual preseason forecasts made by ADF&G were usually calculated as the mean of estimates obtained from models using either spawner-recruit, sibling, or smolt data. Forecasts from this method, referred to as the ADF&G method, had a mean absolute percent error (MAPE) of 37.0 for 1961-82 (MAPE range= 2.7 - 78.0; Fried and Yuen 1987; Fried et al. 1988). Beginning in 1983, attempts were made to improve forecast accuracy by combining results from the ADF&G method with those from other methods (Eggers et al. 1983a, 1983b; Fried and Yuen 1985, 1986, 1987). However, these forecasts did not prove to be more accurate than forecasts based solely on the ADF&G method and did not correct the tendency of published forecasts to under-estimate total run size for 18 of the last 20 years (Fried et al. 1988; Appendix A.1).

Methods used to calculate run size predictions were modified again in 1988 in an attempt to remedy these problems (Fried et al. 1988; Fried and Cross 1988, 1990). The omission of data prior to the 1978 return year from all calculations was the most important change in forecast methods. It was felt that models based on recent data would more accurately reflect current trends in sockeye salmon production. Most Bristol Bay river systems have shown a dramatic increase in the number of sockeye salmon adults produced by each spawner since 1978, coincident with (1) decreased interception of maturing sockeye salmon on the high seas, (2) the onset of more favorable climatic conditions, and (3) improvements in ADF&G's ability to determine and attain spawning escapement goals for most major Bristol Bay systems (Eggers et al. 1984).

Although forecasts based on only recent data decreased under-forecasting errors for river systems on the east side of Bristol Bay, there was still a tendency to under-forecast the run (eight out of the last ten years). In 1991, 1992, and 1993 Cross et al. (1992, 1993, 1994) adjusted the forecast to correct the continuing bias of under-forecasting. Several bias correction factors were evaluated in search of the most accurate forecast. The goal was an unbiased forecast resulting in no tendency to over- or under-forecast. In 1994 we continued to analyze bias correction factors, and methods used were similar to those for the 1992 and 1993 forecasts.

The purpose of this report is to provide a final preseason forecast of sockeye salmon returning to Bristol Bay, Alaska, in 1994 with an outlook of abundance fluctuations through 1997. Specific objectives are to (1) document changes in methods used to forecast Bristol Bay sockeye salmon runs in 1994, (2) evaluate the relative accuracy of different forecasting methods, (3) forecast annual runs for all major river systems through 1997, and (4) indicate where actual runs are most likely to depart from preseason expectations.

METHODS

Age Designation

Sockeye salmon ages were expressed according to European system designations (Koo 1962), wherein the number of annuli formed in fresh and saltwater are indicated to the left and right of a decimal point. Historically, four age classes account for about 98% of total returns: 28% were age 1.2, 31% were age 2.2, 28% were age 1.3, and 11% were age 2.3. Smolt ages were expressed as either age 1. or 2., corresponding to sockeye salmon that migrated seaward in either their second or third year of life.

Forecast Data Base and Techniques

The ADF&G method forecast has been used to predict the number of sockeye salmon by major age class returning to ninc river systems that account for about 98% of Bristol Bay sockeye salmon production, these are: Kvichak, Branch, Naknek, Egegik, Ugashik, Wood, Igushik, Nushagak, and Togiak Rivers (Figure 1). Forecasts for each system and age class have been calculated by averaging results of several models which used either (1) spawner-recruit, (2) sibling, or (3) smolt data. Estimates of numbers of spawners, recruits by age, and siblings by are documented annually in a catch and escapement report (Stratton and Crawford *in press*). Estimates of numbers of smolt by year are taken from Crawford and Cross 1994.

Predictions for the Nushagak River drainage have only been made since 1992. Prior to 1992, forecasts were made for Nuyakuk River, a major tributary of the Nushagak River. A sonar project to count adult salmon entering the Nushagak River mainstem has operated since 1979. The 1994 forecast for Nushagak River was calculated from spawner-recruit and sibling models built from 1982-93 escapement return data.

Prior to 1986, predictions for each data component were calculated by averaging results from two or more models (e.g. linear regression, ratio estimator, mean proportion; Eggers et al. 1983a, 1983b). Beginning in 1986, only results from a single model per component (spawner-recruit, sibling, or smolt) were calculated and averaged for the forecast (Fried and Yuen 1986, 1987).

Forecasts for 1994 were first calculated using all available data (referred to as the All Data ADF&G method) and then recalculated with all data prior to the 1978 return year excluded from calculations (referred to as the Recent Data ADF&G method).

Predicted returns from spawner-recruit data were based on a linear form of the Ricker (1954) curve constructed for age-specific returns (Brannian et al. 1982):

$$\ln\left(\frac{R_{a,r,y}}{E_{r,y}}\right) = \ln(\alpha) + \beta E_{r,y} + \epsilon \qquad (1)$$

where:

$R_{a,r,y}$ = number of age-a sockeye salmon returning to river system r from brood year y,

$E_{r,y}$ = total number of spawners in river system r during brood year y,

α, β = regression coefficients estimated by least square methods, and

ϵ = random error with mean, 0, and variance σ^2.

In cases where the Ricker relationship was not significant at the 25% level (F-test, Ho: $\beta = 0$, $P > 0.25$; Snedecor and Cochran 1969), a linear regression model based on natural logarithm transformed data was used:

$$\ln(R_{a,r,y}) = \alpha + \beta \ln(E_{r,y}) + \epsilon \qquad (2)$$

Predicted returns from sibling (younger age classes from the same brood year) and smolt data were also based upon linear regression models using natural logarithm transformed data, as suggested by Peterman (1982a, 1982b):

$$\ln(R_{a,r,y}) = \alpha + \beta \ln(S_{j,r,y}) + \epsilon \qquad (3)$$

where:

$S_{j,r,y}$ = either the number of age-*j* smolt (where j = age 1. or 2.) migrating from river system *r* which were progeny of brood year *y*, or the number of age-*j* adults (where j =[a-1]) returning to river system *r* from spawning in brood year *y*.

Smolt data were available for three of the nine forecasted river systems. Smolt enumeration programs using sonar equipment were begun in 1971 for Kvichak (Russell 1972), 1982 for Egegik (Bue 1984), and 1983 for Ugashik (Fried et al. 1987) River systems.

Results from models were excluded from final forecast calculations if the model was not significant at the 25% level ($P > 0.25$). If a model was not significant for a river system age class, the mean return of that age class to that river system was used as the prediction. For All Data ADF&G method forecasts, mean returns for all past years (1956-93) were used. For Recent Data ADF&G method forecasts, mean returns for the past 16 years 1978-93, were used. In past years, results from models were also excluded if the input variable ($E_{r,y}$ or $S_{j,r,y}$) was outside the range of data used to build the model. However, results from regression models in which the input data were out-of-range were used in 1994.

Evaluation of Forecast Performance

Comparison of Recent and All Data Forecasts

Since the Recent Data ADF&G method was first used for the 1988 forecast, a hindcasting procedure in which only data prior to the year of interest were used to build models was used to simulate past performance for several years. Due to the limited amount of data available (all data prior to the 1978 return year were omitted from analyses), Recent Data ADF&G method hindcasts could be calculated for only ten years, 1984-93. Hindcasts prior to 1984 could not be calculated because models were not significant at the 25% level ($P > 0.25$).

Recent Data ADF&G method hindcasts for 1984-93 were compared with All Data ADF&G method hindcasts for the same period to determine which method could be expected to produce less biased and more accurate forecasts. Three statistics were used for comparisons: percent error (PE), mean percent error (MPE), and mean absolute percent error (MAPE). PE is a measure of annual performance:

$$PE = 100\left(\frac{F_{i,r} - A_{i,r}}{A_{i,r}}\right) \tag{4}$$

where:

$F_{i,r}$ = forecasted total return of sockeye salmon for year *i* and river system *r*, and

$A_{i,r}$ = actual total return of sockeye salmon for year *i* and river system *r*.

MPE is a measure of bias:

$$MPE = \frac{\sum_{i=1}^{N} 100\left(\frac{F_{i,r} - A_{i,r}}{A_{i,r}}\right)}{N} \tag{5}$$

where:

N = number of years.

MAPE is measure of overall accuracy which treats under- and over-forecasting errors similarly:

$$MAPE = \frac{\sum_{i=1}^{N} 100\left(\frac{|F_{i,r} - A_{i,r}|}{A_{i,r}}\right)}{N} \tag{6}$$

Modeling Historic Forecast Errors

In an effort to reduce the tendency to under-forecast Bristol Bay runs, we looked at ways to model historic forecast errors and develop a bias adjustment factor for the 1994 forecast. We investigated the trends in forecast errors for predictions based on All Data and Recent Data, we compared eastside versus westside forecast errors and individual river system forecast errors.

Predictions based on All Data were hindcasted for years 1965-93 using the same methods described above for the 1994 forecast. Errors in numbers of fish for the 1965-93 All Data forecasts were modeled using a linear regression model:

$$Y_i = \alpha + \beta i + \epsilon \qquad (7)$$

and a second-order polynomial regression model:

$$Y_i = \alpha + \beta_1 i + \beta_2 i^2 + \epsilon \qquad (8)$$

where:

Y_i = predicted run - actual run for year i,

α, β = regression coefficients estimated by least square methods, and

ϵ = random error with mean, 0, and variance σ^2.

The evaluation of forecast errors for the 1992 forecast included modeling All Data forecast errors with Box-Jenkins forecasting procedures (Chatfield 1984; Cross et al. 1993). This procedure was not repeated during evaluation of the 1994 forecast.

Predictions based on Recent Data were hindcasted only for years 1984-93 because of the limited data base. With only ten years of Recent Data forecast errors available, regression modeling techniques could not be used. Therefore, an adjustment factor for the 1994 forecast was estimated by taking the mean percent error from 1984-93 Recent Data forecasts.

Forecast errors were analyzed by individual river system and for eastside systems combined versus westside systems combined. For the 1991 and 1992 forecasts, we adjusted the total eastside forecast and the total westside forecast by a combined correction factor. For the 1993 and 1994 forecasts, we decided to adjust each individual river's forecast by its own average forecast error. We decided to use individual forecast adjustments because the errors have varied considerably among rivers. We were concerned that using one adjustment for the entire eastside and the entire westside of Bristol Bay would result in overforecasting some systems (Kvichak River) while under forecasting other systems (Egegik River).

Confidence Intervals

The 80% confidence interval (80% CI) for the total run forecast was calculated as:

$$80\%\ CI = F \pm t_{0.2} s_F \tag{9}$$

where:

F = forecasted total run of sockeye salmon to all of Bristol Bay (total of river system predictions) in 1994,

s_F = standard error of the forecasted total run of sockeye salmon to Bristol Bay in 1994, and

$t_{0.2}$ = Student's t value with a probability of type I error of 0.20, and N-1 df.

Estimation of (s_F) was based on the mean squared error (MSE) calculated from 1984-93 total run predictions using the same techniques as 1994:

$$s_f = \sqrt{MSE}\ , \tag{10}$$

$$MSE = \frac{\sum_{i=1}^{N} (F_i - A_i)^2}{N - 1} \qquad (11)$$

where:

F_i = forecasted total return of sockeye salmon for year *i*,

A_i = actual total return of sockeye salmon for year *i*, and

N = number of years (1984-93).

Outlook to 1997

Forecasts were made for 1995, 1996, and 1997 using only spawner-recruit data (Equation 1 or 2). These forecasts were not adjusted for historic forecast errors.

RESULTS

Performance of Recent and All Data Forecasts

Justification for use of the Recent Data ADF&G method was based on the observation that the number of returning adults produced per spawner has increased dramatically since 1978 (Fried et al. 1988). It was hoped that use of only recent data would provide a more accurate estimate of total sockeye salmon returns and would help correct the past under-forecasting bias of annual runs. If results for 1984-93 are representative of future performance, then forecasts of total sockeye salmon returns to Bristol Bay based on the Recent Data ADF&G method should be less biased (MPE=-17.3) and more accurate (MAPE=25.9) than forecasts based on the All Data ADF&G method (MPE=-43.3; MAPE=43.3; Appendix B.1).

Unfortunately, results for individual river systems strongly suggested that the All Data ADF&G method was more accurate and less biased for Wood, Igushik, Nuyakuk/Nushagak, and Togiak than the Recent Data method (Appendix B.1). Results for Nushagak and

Togiak District systems based on the Recent Data ADF&G method showed a two- to three-fold decrease in accuracy as well as a large over-forecasting bias when compared to results based on the All Data ADF&G method. Results for Kvichak River suggested that the Recent Data method was less biased than the All Data method (Recent MPE=8.6, All MPE=-21.3) but less accurate (Recent MAPE=55.5, All MAPE=46.8).

We tried to balance gains and losses in total Bristol Bay and individual river system forecast bias and accuracy by using results of the Recent Data ADF&G method for some systems and the All Data ADF&G method for the remaining systems. For the 1994 forecast, we used Recent Data for eastside river systems (Kvichak, Branch, Naknek, Egegik, and Ugashik) and All Data for westside river systems (Wood, Igushik, Nushagak, and Togiak). This method is similar to that used for the 1989-93 forecasts and is referred to as the Mixed Data ADF&G method (Appendix B.2). We felt it would provide the least biased and most accurate (MPE=-25.5, MAPE=28.6) forecast of total returns to Bristol Bay and would also furnish reasonable individual river system forecasts.

Out-Of-Range Data

Egegik River was the only system which had input variables (parent escapement, sibling, and smolt) which were outside the data ranges used to build the model. These variables were: (1) the 1990 escapement or parent year for 1994 age-1.2 returns; (2) the 1991 age-2 smolt outmigration which are returning as age-2.3 adults in 1994; and (3) the 1993 return of age-2.2 sockeye salmon which are siblings to age-2.3 returns in 1994. Although there is a high degree of uncertainty when a model is used to predict an outcome outside its existing values, we felt that using the out-of-range input variables in the regression models was preferable to excluding the information. To help us decide whether or not to use out-of-range data, we looked at the difference in forecast accuracies for years 1984-93 when out-of-range data were included and excluded. The MPE of Egegik forecasts for 1984-93 in which out-of-range data were not used was -69.6% compared to -53.6% when out-of-range data were included.

Unadjusted River System Forecasts

Kvichak River

Spawner-recruit, sibling, and smolt data bases were available for estimating Kvichak River run sizes in 1994.

Age 1.2. The age-1.2 forecast for this system was based upon spawner-recruit and smolt data (Appendix C.1). A prediction based on sibling data was not used because the regression model was not significant at the 25% level ($P > 0.25$). The spawner-recruit estimate of 3,358,000 was 119% greater than the smolt estimate of 1,532,000. The average of the two estimates was 2,545,000 sockeye salmon.

Age 2.2. The age-2.2 forecast was based upon spawner-recruit, sibling, and smolt data (Appendix C.1). The smolt estimate of 5,290,000 was 36% lower than the spawner-recruit estimate of 8,228,000 which was 47% lower than the sibling estimate of 15,563,000. The average of the three estimates was 9,694,000 sockeye salmon.

Age 1.3. The age-1.3 forecast was based upon spawner-recruit, sibling, and smolt data (Appendix C.1). The spawner-recruit estimate of 2,229,000 was 88% greater than the sibling estimate of 1,185,000 and 42% greater than the smolt estimate of 1,566,000. The average of the three estimates was 1,660,000 sockeye salmon.

Age 2.3. The age-2.3 forecast was based upon spawner-recruit, sibling, and smolt data (Appendix C.1). The spawner-recruit estimate of 853,000 was about 25% greater than the sibling estimate of 681,000, and 45% greater than the smolt estimate of 587,000. The average of the three estimates was 707,000 sockeye salmon.

Branch River

Spawner-recruit and sibling data bases were available for estimating Branch River run sizes in 1994. There has never been a smolt project on the Branch River.

Age 1.2. The age-1.2 forecast was based upon spawner-recruit and sibling data (Appendix C.2). The spawner-recruit estimate of 211,000 was similar to the sibling estimate of 206,000. The average of the two estimates was 209,000 sockeye salmon.

Age 2.2. The age-2.2 forecast was based only upon spawner-recruit data (Appendix C.2). A prediction based on sibling data was not used because the model was not significant at the 25% level ($P > 0.25$). The spawner-recruit estimate was 44,000 sockeye salmon.

Age 1.3. The age-1.3 forecast was based only upon spawner-recruit data (Appendix C.2). The prediction based on sibling data was not used because the model was not significant at the 25% level ($P > 0.25$). The spawner-recruit estimate was 167,000 sockeye salmon.

Age 2.3. The age-2.3 forecast was based upon spawner-recruit and sibling data (Appendix C.2). The spawner-recruit estimate of 11,000 was 62% less than the sibling estimate of 29,000. The average of the two estimates was 20,000 sockeye salmon.

Naknek River

Spawner-recruit and sibling data bases were available for estimating Naknek River run sizes in 1994. The smolt project on the Naknek River operated from 1982-86 and again in 1993.

Age 1.2. The age-1.2 forecast was based only upon spawner-recruit data (Appendix C.3). A prediction based on sibling data could not be made because no age-1.1 sockeye salmon were present in 1993 Naknek River samples. The spawner-recruit estimate was 740,000 sockeye salmon.

Age 2.2. The age-2.2 forecast was also based only upon spawner-recruit data (Appendix C.3). A predictions based on sibling data was not used because the model was not significant at the 25% level ($P > 0.25$). The spawner-recruit estimate was 660,000 sockeye salmon.

Age 1.3. The age-1.3 forecast was based on spawner-recruit and sibling data (Appendix C.3). The spawner-recruit estimate of 1,328,000 was 61% greater than the sibling estimate of 823,000. The average of the two estimates was 1,076,000 sockeye salmon.

Age 2.3. The age-2.3 forecast was based on spawner-recruit and sibling data (Appendix C.3). The spawner-recruit estimate of 844,000 was similar to the sibling estimate of 810,000. The average of the two estimates was 827,000 sockeye salmon.

Egegik River

Spawner-recruit, sibling, and smolt data bases were available for estimating 1994 Egegik River run sizes.

Age 1.2. The age-1.2 forecast was based on spawner-recruit and smolt data (Appendix C.4). A prediction based on sibling data could not be made because no age-1.1 sockeye salmon were present in 1993 Egegik River samples. The spawner-recruit estimate of 217,000 was 65% less than the smolt estimate of 623,000. The average of the two estimates was 420,000 sockeye salmon.

Age 2.2. The age-2.2 forecast was based upon spawner-recruit, sibling, and smolt data (Appendix C.4). The spawner-recruit estimate of 6,899,000 was 51% greater than the sibling estimate of 4,557,000, and 108% greater than the smolt estimate of 3,323,000. The average of the three estimates was 4,926,000 sockeye salmon.

Age 1.3. The age-1.3 forecast was based upon sibling, and smolt data (Appendix C.4). A prediction based on spawner-recruit data was not used because the model was not significant at the 25% level (P > 0.25). The sibling estimate of 1,091,000 was 12% less than the smolt estimate of 1,238,000. The average of the two estimates was 1,165,000 sockeye salmon.

Age 2.3. The age-2.3 forecast for this system was based upon spawner-recruit, sibling, and smolt data (Appendix C.4). The spawner-recruit estimate of 2,599,000 was 41% less than the sibling estimate of 4,403,000, and 76% less than the smolt estimate of 11,105,000. The average of the three estimates was 6,036,000 sockeye salmon.

Ugashik River

Spawner-recruit and sibling data bases were available for estimating all age groups of 1994 Ugashik River run sizes. Only age-1.3 and age-2.3 sockeye salmon returning to Ugashik River could be predicted from smolt data because the smolt project did not operate in 1992.

Age 1.2. The age-1.2 forecast was based upon spawner-recruit and sibling data (Appendix C.5). The spawner-recruit estimate of 656,000 was 16% less than the sibling estimate of 781,000. The average of the two estimates was 719,000 sockeye salmon.

Age 2.2. The age-2.2 forecast was based upon spawner-recruit and sibling data (Appendix C.5). The spawner-recruit estimate of 2,287,000 was 42% greater than the sibling estimate of 1,609,000. The average of the two estimates was 1,948,000 sockeye salmon.

Age 1.3. The age-1.3 forecast was based upon spawner-recruit, sibling, and smolt data (Appendix C.5). The spawner-recruit estimate of 1,801,000 was 110% greater than the sibling estimate of 856,000 and 105% greater than the smolt estimate of 879,000. The average of the three estimates was 1,179,000 sockeye salmon.

Age 2.3. The age-2.3 forecast was based upon spawner-recruit and sibling data (Appendix C.5). The prediction based on smolt data was not used because the model was not significant at the 25% level (P > 0.25). The spawner-recruit estimate of 497,000 was 36% less than the sibling estimate of 783,000. The average of the two estimates was 640,000 sockeye salmon.

Wood River

Spawner-recruit and sibling data bases were available for estimating Wood River run sizes in 1994. Smolt emigrating from the Wood River were last counted in 1990.

Age 1.2. The age-1.2 forecast was based upon spawner-recruit and sibling data (Appendix C.6). The spawner-recruit estimate of 932,000 was 49% greater than the sibling estimate of 623,000. The average of the two estimates was 778,000 sockeye salmon.

Age 2.2. The age-2.2 forecast was based only upon spawner-recruit data (Appendix C.6). A prediction based on sibling data could not be made because no age-2.1 samples were present in the 1993 Wood River samples. The spawner-recruit estimate was 101,000 sockeye salmon.

Age 1.3. The age-1.3 forecast was based upon spawner-recruit and sibling data (Appendix C.6). The spawner-recruit estimate of 1,022,000 was similar to the sibling estimate of 1,097,000. The average of the two estimates was 1,060,000 sockeye salmon.

Age 2.3. The age-2.3 forecast was based on spawner-recruit and sibling data (Appendix C.6). The spawner-recruit estimate of 55,000 was similar to the sibling estimate of 52,000. The average of the two estimates was 54,000 sockeye salmon.

Igushik River

Spawner-recruit and sibling data bases were available for estimating Igushik River run sizes in 1994. There has never been a smolt project on the Igushik River.

Age 1.2. The age-1.2 forecast was based only upon results from spawner-recruit data (Appendix C.7). A prediction based on sibling data was not made because no age-1.1 sockeye salmon were present in samples collected from Igushik River in 1993. The spawner-recruit estimate was 123,000 sockeye salmon.

Age 2.2. The age-2.2 forecast was based only on spawner-recruit data (Appendix C.7). A prediction based on sibling data was not made because no age-2.1 sockeye salmon were present in samples collected from Igushik River in 1993. The spawner-recruit estimate was 45,000 sockeye salmon.

Age 1.3. The age-1.3 forecast was based upon spawner-recruit and sibling data (Appendix C.7). The spawner-recruit estimate of 566,000 was 14% less than the sibling estimate of 656,000. The average of the two estimates was 611,000 sockeye salmon.

Age 2.3. The age-2.3 forecast was based upon spawner-recruit and sibling data (Appendix C.7). The spawner-recruit estimate of 30,000 was 21% less than the sibling estimate of 38,000. The average of the two estimates was 34,000 sockeye salmon.

Nushagak River

Reliable age information for sockeye salmon returning to Nushagak River was available from 1982-93 return years. Spawner-recruit and sibling data bases from 1982-93 return years were used to predict Nushagak River run sizes in 1994.

Age 0.2. The age-0.2 forecast was based only upon spawner-recruit data (Appendix C.8). A prediction based on sibling data could not be made because no age-0.1 sockeye salmon were present in samples collected from Nushagak River in 1993. The spawner-recruit estimate was 43,000 sockeye salmon.

Age 1.2. The age-1.2 forecast was based only upon results from spawner-recruit data (Appendix C.8). A prediction based on sibling data was not made because no age-1.1 sockeye salmon were present in samples collected from Nushagak River in 1993. The spawner-recruit estimate was 131,000 sockeye salmon.

Age 2.2. The age-2.2 forecast was based on the 1982-93 mean returns of age-2.2 sockeye salmon to Nushagak River (Appendix C.8). A prediction based on spawner-recruit was not used because the model was not significant at the 25% level ($P > 0.25$). A prediction based on sibling data was not made because no age-2.1 sockeye salmon were present in samples collected from Nushagak River in 1993. The mean return of age-2.2 sockeye salmon was 22,000 sockeye salmon.

Age 0.3. The age-0.3 forecast was based on spawner-recruit and sibling data bases (Appendix C.8). The spawner-recruit estimate of 512,000 was similar to the sibling estimate of 523,000. The average of the two estimates was 518,000 sockeye salmon.

Age 1.3. The age-1.3 forecast was based upon spawner-recruit and sibling data (Appendix C.8). The spawner-recruit estimate of 831,000 was 10% greater than the sibling estimate of 756,000. The average of the two estimates was 794,000 sockeye salmon.

Age 2.3. The age-2.3 forecast was based only upon sibling data (Appendix C.8). A prediction based on spawner-recruit was not used because the model was not significant at the 25% level ($P > 0.25$). The sibling estimate was 14,000 sockeye salmon.

Age 0.4. The age-0.4 forecast was based on spawner-recruit and sibling data bases (Appendix C.8). The spawner-recruit estimate of 61,000 was similar to the sibling estimate of 69,000. The average of the two estimates was 65,000 sockeye salmon.

Togiak River

Spawner-recruit and sibling data bases were available for estimating Togiak River run sizes in 1994. A smolt project was operated on Togiak River only in 1988.

Age 1.2. The age-1.2 forecast was based only on spawner-recruit data (Appendix C.9). A prediction based on sibling data was not made because no age-1.1 sockeye salmon were present in samples collected from Togiak River in 1993. The spawner-recruit estimate was 110,000 sockeye salmon.

Age 2.2. The age-2.2 forecast was based only on spawner-recruit data (Appendix C.9). A prediction based on sibling data was not made because no age-2.1 sockeye salmon were present in 1993 Togiak River samples. The spawner-recruit estimate was 23,000 sockeye salmon.

Age 1.3. The age-1.3 forecast was based on spawner-recruit and sibling data (Appendix C.9). The spawner-recruit estimate of 193,000 was 31% less than the sibling estimate of 279,000. The average of the two estimates was 236,000 sockeye salmon.

Age 2.3. The age-2.3 forecast for this system was based on spawner-recruit and sibling data (Appendix C.9). The spawner-recruit estimate of 28,000 was similar to the sibling estimate of 30,000. The average of the two estimates was 29,000 sockeye salmon.

Historic Forecast Errors and 1994 Forecast Adjustments

All Data Forecast Errors

Eastside. Forecast errors for eastside river systems based on All Data showed an increasing trend from 1966-93 (Figure 2). Linear and polynomial regression models of the relationship between forecast year and eastside forecast error were significant ($P < 0.01$; Figures 3, 4). The 1994 prediction for combined eastside systems based on All Data was 29.0 million sockeye salmon. The estimated error for the 1994 prediction based on the linear and polynomial regression models were -22.0 million and -25.4 million (Table 1). Estimated error adjustments for an eastside All Data prediction were similar to the original prediction (Table 1).

The performance of using All Data to predict eastside systems and correcting the prediction by an adjustment factor based on regression models was evaluated by hindcasting runs with these techniques. Correcting All Data predictions by errors estimated from linear regression models resulted in over-forecasts for 1984-88 and under-forecasts for 1989-93 (Figure 5). The MPE of All Data predictions corrected by linear regression models was +3% for 1984-93 compared to -95% for unadjusted predictions.

Westside. Errors of westside forecasts (Wood, Igushik, and Togiak) based on All Data showed a definite trend towards under forecasting (20 out of 27 years), but the under-forecasting errors were not correlated with year (Figure 6). Linear and polynomial regression models of the relationship between year and westside forecast error were not significant ($P > 0.25$; Figures 7, 8). The 1994 prediction for combined westside systems (Wood, Igushik, and Togiak) based on All Data was 3.2 million sockeye salmon (Table 1). The estimated error for the 1994 prediction based on the linear and polynomial regression models were -2.5 million and -1.5 million (Table 1). Because the regression models of combined westside (All Data) forecast errors were not statistically significant, we also looked at the 1984-93 average error of All Data forecasts. We only looked at 1984-93 because we wanted to see how All Data forecasts for Wood, Igushik, and Togiak Rivers performed in more recent years. The 1984-93 average error of All Data forecasts for Wood, Igushik, and Togiak Rivers was -1.3 million (-40%).

The performance of using All Data to predict westside systems and correcting the prediction by an adjustment factor based on a linear regression model or the 1984-93 average error was reviewed by hindcasting runs with these techniques. Correcting All Data westside predictions by errors estimated from linear regression models resulted in over-forecasts for 1984-90 and 1992, and an under-forecast for 1991 and 1993 (Figure 9). The MPE of All Data westside predictions corrected by linear regression models was +24% for 1984-93 compared to -40% for unadjusted predictions. Correcting All Data westside predictions by the 1984-93 average error resulted in under-forecasts for 1987-93 (Figure 9). The MPE of All Data westside predictions corrected by the 1984-93 average error was -39% for 1987-93 compared to -61% for unadjusted predictions.

Recent Data Forecast Errors

Eastside. Errors of eastside forecasts based on Recent Data were generally negative (forecasted run less than actual run), and showed a slight trend of being increasingly negative through the years from 1984-93 (Figure 10). Because there were so few years of Recent Data, an average of the errors was calculated rather than using other modeling techniques. The 1984-93 average error of -37% was used as an estimate of the 1994 prediction error. The 1994 prediction for combined eastside systems based on Recent Data was 35.4 million fish. The estimated error for the 1994 eastside prediction based on average errors was -13.3 million fish (Table 1). Using the average error to adjust Recent Data forecasts for eastside systems resulted in under-forecasts in 1989-93 and over-forecast for 1987-88 (Figure 10). The 1987-93 MPE for Recent Data eastside forecasts was reduced from -46% to -19% by adjusting for previous years average error.

Westside. Errors of westside (Wood, Igushik, Togiak) forecasts based on Recent Data were generally positive (forecasted run more than actual run), and errors decreased through time for 1984-93 (Figure 11). The 1984-93 average error (+12%) was used as an estimate of the 1994 prediction error. The 1994 prediction for combined westside systems (Wood, Igushik, Togiak) based on Recent Data was 5.3 million fish. The estimated error for the 1994 westside prediction based on average errors was +0.6 million fish (Table 1). Using the average error to adjust Recent Data forecasts for westside systems resulted in under-forecasts for 1987-93 (Figure 11). The 1987-93 MPE for Recent Data westside forecasts was increased from +0.6% to -63% by adjusting for previous years average error. Because errors of Recent Data westside forecasts decreased through time, correcting by a simple average decreased rather than improved the accuracy of the more recent years' predictions.

Mixed Data Forecast Errors For Individual Rivers

Kvichak River. Errors in Kvichak River forecasts based on Recent Data showed no trend from 1984-93 (Figure 12). The 1994 Recent Data prediction for Kvichak River was 14.6 million. The estimated error for the 1994 prediction based on average errors was -4.4 million fish (Table 1). Using average errors to adjust Recent Data forecasts for Kvichak River resulted in a very large under-forecast in 1987 and improved accuracy in 1988-91, and over-forecasts in 1992-93 (Figure 12). The 1987-93 MPE for Recent Data Kvichak River forecasts was reduced from -44% to -19% by adjusting for previous years average error.

Branch River. Errors in Branch River forecasts based on Recent Data showed a trend of being increasingly negative from 1984-93 (Figure 13). The 1994 Recent Data prediction for Branch River was 0.4 million. The estimated error for the 1994 prediction based on average errors was -0.1 million fish (Table 1). The 1987-93 MPE for Recent Data Branch River forecasts was increased slightly from -33% to -36% by adjusting for previous years average error (Figure 13). Although the 1987-93 MPE increased slightly, errors for all years (1987-93) except 1989 were reduced.

Naknek River. Errors in Naknek River forecasts based on Recent Data showed no trend from 1984-93 (Figure 14). The 1994 Recent Data prediction for Naknek River was 3.3 million. The estimated error for the 1994 prediction based on average errors was -0.8 million fish (Table 1). The 1987-93 MPE for Recent Data Naknek River forecasts was increased from -42% to -48% by adjusting for previous years average error (Figure 14). Although the 1987-93 MPE increased, errors for 1987-88 and 1991-93 were reduced significantly. The MPE was increased because over- and under-forecasting errors did not compensate each other as much.

Egegik River. Egegik River forecasts based on Recent Data were all significantly less than observed runs from 1984-93 (Figure 15). The 1994 Recent Data prediction for Egegik River was 12.5 million. The estimated error for the 1994 prediction based on average errors was -7.6 million fish (Table 1). Using average errors to adjust Recent Data forecasts for Egegik River resulted in over-forecasts in 1987-88 and 1991 and under-forecasts in 1989-90 and 1992-93 (Figure 15). The 1987-93 MPE for Recent Data Egegik River forecasts was reduced from -67% to -14% by adjusting for previous years average error.

Ugashik River. Errors in Ugashik River forecasts based on Recent Data showed no trend from 1984-93 (Figure 16). The 1994 Recent Data prediction for Ugashik River was 4.5 million. The estimated error for the 1994 prediction based on average errors was -1.5 million fish (Table 1). The 1987-93 MPE for Recent Data Ugashik River forecasts was reduced from -25% to -1% by adjusting for previous years average error (Figure 16).

Wood River. Errors in Wood River forecasts based on All Data were positive and negative from 1984-88, but were all negative since 1989 (Figure 17). The 1994 All Data prediction for Wood River was 2.0 million. The estimated error for the 1994 prediction based on average errors was -0.5 million fish (Table 1). The 1987-93 MPE for All Data Wood River forecasts was reduced from -44% to -36% by adjusting for previous years average error (Figure 17).

Igushik River. Igushik River forecasts based on All Data were generally less than observed runs from 1984-93 (Figure 18). The 1994 All Data prediction for Igushik River was 0.8 million. The estimated error for the 1994 prediction based on average errors was -0.8 million fish (Table 1). The 1987-93 MPE for All Data Igushik River forecasts was reduced from -127% to -60% by adjusting for previous years average error (Figure 18).

Togiak River. Togiak River forecasts based on All Data were not consistently greater or less than observed runs from 1984-93 (Figure 19). The 1994 All Data prediction for Togiak River was 0.4 million. The estimated error for the 1994 prediction based on average errors was -0.2 million fish (Table 1). The 1987-93 MPE for All Data Togiak River forecasts was reduced from -53% to -27% by adjusting for previous years average error (Figure 19).

1994 Forecast Adjustment

Errors in All Data eastside forecasts showed an increasing trend from 1966-93. However, they were clustered in two groups. Prior to 1978 forecasts were generally greater than or equal to actual runs and after 1978 forecasts were less than actual runs (Figure 2). Because eastside errors appeared to be clustered in time, we felt that regression analysis was not appropriate. In addition, regression models estimated adjustment factors for the 1994 eastside All Data forecast which were larger than the original forecast. We decided that using Recent Data to forecast eastside systems and adjusting by a smaller number of fish was preferable to using the entire data base (All Data) and adjusting by a very large number. Therefore, we decided to use the Recent Data forecast for the eastside systems. We also decided to adjust individual river forecasts by their average forecast error rather than adjusting the entire eastside forecast by the combined error and prorating that error among rivers. While forecasts for eastside rivers had, in general, been low, the percentage of under-forecasting varied considerably among the rivers. The 1984-93 forecast error for Egegik River was -60%, while that for Branch River was only -19%. We were concerned that adjusting the total eastside forecast by the combined error would continue the trend to under-forecast some rivers (i.e. Egegik) and over-forecast other rivers (i.e. Kvichak). Therefore, we felt it was more appropriate to adjust each eastside river by its forecast error. The 1994 Recent Data forecasts by eastside river were increased by: 30.1% for Kvichak, 19.0% for Branch, 25.4% for Naknek, 60.5% for Egegik, and 32.8% for Ugashik River.

Based on hindcasting results, using All Data to forecast westside systems is less biased and more accurate (MPE=-23%, MAPE=25%) than Recent Data (MPE=39%, MAPE=53%). Recent Data forecasts for westside systems were greater than the actual run in six of ten years. Because All Data appeared to forecast west side systems more accurately, we decided to use All Data instead of Recent Data. Linear and polynomial regression models of All Data westside forecast errors were not significant, therefore we did not use regression analysis. Instead, we increased the 1994 All Data westside river forecasts by their individual 1984-93 average errors. The 1994 All Data forecasts by river were increased by: 26.0% for Wood River, 93.8% for Igushik River, and 38.9% for Togiak River.

Adjusted Total Bristol Bay Forecast

Based on results of the Mixed Data method adjusted by individual rivers 1984-93 average percent error, a total of 55,991,000 sockeye salmon (80% CI: 41,308,000 - 70,674,000) are expected to return to Bristol Bay in 1994 (Table 2). A run of this size would be the third highest run since 1956, the first year of total run information. The 1994 prediction is 60% (21,100,000 sockeye salmon) greater than the 20-year (1974-93) mean return of 34,891,000 (range: 10,671,000 to 66,293,000), and about 40% (16,082,000) greater than the most recent 10-year (1984-93) mean return of 39,909,000 (range: 23,996,000 - 55,026,000).

Total projected sockeye salmon harvest is 43,206,000 (80% CI: 28,523,000 - 57,889,000; Table 2). Most (39,620,000) of this harvest will be taken within Bristol Bay inshore fishing districts (Table 3). The remainder of the sockeye harvest (8.3% of total Bristol Bay harvest = 3,586,000) has been allocated to fisheries occurring in June in the vicinity of Shumagin Islands and South Unimak under an existing management plan (regulation 5AAC 09.365, ADF&G 1992). No estimate is available of the number of Bristol Bay sockeye salmon expected to be harvested by foreign or domestic high seas fisheries.

The total number of sockeye salmon expected to return to Bristol Bay, after the Shumagin Islands and South Unimak fisheries have occurred is 52,405,000 (Table 3). Runs should exceed spawning escapement goals for all river systems. The projected Bristol Bay combined fishing district harvest of 39,620,000 would be 96% (19,418,000) greater than the 20-year (1974-93) mean harvest of 20,202,000 (range: 1,334,000 - 40,773,000), and 56% (14,182,000) greater than the 10-year (1984-93) mean harvest of 25,438,000 (range: 13,841,000 - 40,773,000).

Adjusted River System Forecasts

Forecasts by river were increased by 30.1% for Kvichak, 19.0% for Branch, 25.4% for Naknek, 60.5% for Egegik, 32.8% for Ugashik River, 26.0% for Wood River, 93.8% for Igushik River, and 38.9% for Togiak River.

Kvichak River

A total of 19,000,000 sockeye salmon were forecasted to return to this system (Table 3). Sockeye salmon production within Kvichak River has followed a five-year abundance cycle (Mathisen and Poe 1981). A return of 19,000,000 sockeye salmon to the Kvichak River system in 1994, a pre-peak year, would be about 46% greater than the mean return of 12,971,000 sockeye salmon (range: 1,010,000 - 25,297,000) observed during past "pre-peak" years (1959, 1964, 1969, 1974, 1979, 1984, 1989). Age-2.2 sockeye salmon comprised 66% of the forecasted Kvichak River return (Table 2).

Branch River

A total of 524,000 sockeye salmon were forecasted to return to this system (Table 3). A total run of this size would be about 4% greater than the mean return of 503,000 for 1984-1993 (range: 283,000 - 862,000), and about 15% greater than the mean return of 457,000 for 1974-1993 (range: 129,000 - 862,000). Age-1.2 and age-1.3 comprised 48% and 38% of the Branch River forecast (Table 2).

Naknek River

A total of 4,143,000 sockeye salmon were forecasted to return to this system (Table 3). A total run of this size would be 13% less than the mean return of 4,783,000 for 1984-93 (range: 1,796,000 - 10,353,000) and 4% less than the mean return of 4,298,000 for 1974-93 (range: 1,730,000 - 10,353,000). Age-1.3 and age-2.3 comprised 33% and 25% of the Naknek River forecast (Table 2).

Egegik River

A total of 20,142,000 sockeye salmon were forecasted to return to this system (Table 3). A total run of this size would be about 77% greater than the mean return of 11,403,000 for 1984-93 (range: 6,175,000 - 24,687,000), but about 169% greater than the mean return of 7,479,000 for 1974-93 (range: 1,530,000 - 24,687,000). The 1994 Egegik River forecast was 39% age-2.2 and 48% age-2.3 sockeye salmon (Table 2).

Ugashik River

A total of 5,956,000 sockeye salmon were forecasted to return to this system (Table 3). A total run of this size would be about 22% greater than the mean return of 4,902,000 for 1984-93 (range: 2,256,000 - 7,875,000) and about 75% greater than the mean return of 3,403,000 for 1974-93 (range: 67,000 - 7,875,000). Age-2.2 and age-1.3 sockeye salmon comprised 43% and 26% of the 1994 Ugashik River forecast (Table 2).

Wood River

A total of 2,511,000 sockeye salmon were forecasted to return to this system (Table 3). A total run of this size would be similar to the mean return of 2,580,000 for 1984-93 (range: 1,694,000 - 3,554,000) and about 14% less than the mean return of 2,924,000 for 1974-93 (range: 928,000 - 4,925,000). The 1994 Wood River forecast was comprised of 39% age-1.2 and 53% age-1.3 sockeye salmon (Table 2).

Igushik River

A total of 1,575,000 sockeye salmon were forecasted to return to this system (Table 3). A total run of this size would be about 49% greater than the mean return of 1,058,000 for

1984-93 (range: 415,000 - 2,573,000) and 33% greater than the mean return of 1,180,000 for 1974-93 (range: 164,000 - 3,276,000). Approximately 75% of the 1994 Igushik River forecast was comprised of age-1.3 sockeye salmon (Table 2).

Nushagak River

A total of 1,587,000 sockeye salmon were forecasted to return to this system (Table 3). A total run of his size would be 5% less than the mean return of 1,675,000 for 1984-93 (range: 964,000 - 2,362,000). The 1994 Nushagak River forecast was comprised of 50% age-1.3 and 39% zero freshwater aged sockeye salmon (Table 2).

Togiak River

A total of 553,000 sockeye salmon were forecasted to return to this system (Table 3). A total run of this size would be similar to the mean return of 562,000 for 1984-93 (range: 179,000 - 1,002,000), and 12% less than the mean return of 626,000 for 1974-93 (range: 179,000 - 1,173,000). About 59% of the sockeye salmon forecasted to return to Togiak River in 1994 were age 1.3 (Table 2).

Expected Forecast Performance

Our best estimate of 1994 sockeye run size was based on the Mixed Data method. Subsequently, forecasts for individual river systems were increased by their 1984-93 average percent error. Although this forecast is our best estimate of returning run size, differences among the various forecasting components and methods suggested that deviations would be most likely to occur in three areas:

River System	Most Probable Deviation from Forecasted Return	Reason for Probable Deviation
Kvichak	less than expected return of age-2.2 sockeye salmon	Smolt forecast indicated lower returns of age-2.2 fish than either spawner or sibling forecasts.
Egegik	less than expected return of age-2.2 and age-2.3 sockeye salmon	Smolt forecast indicated lower returns of age-2.2 fish than either spawner or sibling forecasts. Greater than previously recorded

River System	Most Probable Deviation from Forecasted Return	Reason for Probable Deviation
Egegik		sibling and smolt numbers were used in regression models to predict returns of age-2.3 fish. Because these data are out-of-range it is unknown how well the regression will predict.
Ugashik	less than expected return of age-1.3 and age-2.2 sockeye salmon.	Sibling forecast indicated lower returns of age-1.3 and age-2.2 than spawner forecasts.

This is the fourth year ADF&G adjusted the forecast based on historic forecast errors. If the 1994 run is similar to runs occurring in the past ten years, the forecast should be close to the actual run. If the 1994 run is below average, similar to 1986 and 1988 runs, the 1994 forecast will be too high. Other indicators that can be used to assess preseason forecast accuracy will not be available until June 1994 when the Shumagin Islands-South Unimak commercial fishery and the Port Moller offshore test fishery (operated by Fisheries Research Institute, University of Washington) take place. Catch, effort, and age composition data collected from these fisheries have been used in past years with varying degrees of success to modify preseason expectations (Eggers and Shaul 1987; Fried and Hilborn 1988; Yuen and Fried 1985).

Outlook to 1997

Comparisons of 1994-97 forecasts based only on spawner-recruit data not adjusted for historic errors suggested that the total number of sockeye salmon returning to Bristol Bay would be highest in 1994 and similar in 1995-97 (Table 4). Runs to all river systems are not only expected to exceed escapement goals, but also produce high catches similar to the past five years. The reader is cautioned that these long-term predictions are based only on spawner-recruit data and will undoubtedly change as smolt and sibling information become available.

LITERATURE CITED

Alaska Department of Fish and Game (ADF&G). 1961. Forecast of Bristol Bay red salmon run in 1961. Alaska Department of Fish and Game, Division of Commercial Fisheries, Memorandum No. 1, Juneau.

Alaska Department of Fish and Game (ADF&G). 1992. 1992-1994 Bristol Bay and Westward Alaska commercial fishing regulations salmon and miscellaneous finfish. Alaska Department of Fish and Game, Juneau.

Brannian, L. K., O. A. Mathisen, and D. A. McCaughran. 1982. Variance estimates of sockeye salmon predictions with reference to the Egegik River system of Bristol Bay, Alaska. Final Report for the period January 1, 1982-June 30, 1982 to Alaska Department of Fish and Game, Contract No. 82-0769, University of Washington, Fisheries Research Institute, Seattle.

Bue, B. G. 1984. 1982 Egegik River sockeye salmon smolt studies. Pages 28-40 *in* D. M. Eggers and H. J. Yuen, editors. 1982 Bristol Bay sockeye salmon smolt studies. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Data Report 103, Juneau.

Chatfield, C. 1984. The analysis of time series: an introduction. Third Edition. Chapman and Hall, New York.

Crawford, D. L., B. A. Cross. 1994. Bristol Bay sockeye salmon smolt studies for 1993. Alaska Department of Fish and Game, Division of Commercial Fisheries Management and Development, Regional Information Report 2A94-14, Anchorage.

Cross, B. A., B. L. Stratton, and L. K. Brannian. 1992. A synopsis and critique of forecasts of sockeye salmon returning to Bristol Bay, Alaska, in 1991. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 2A92-12, Anchorage.

Cross, B. A., B. L. Stratton, and L. K. Brannian. 1993. A synopsis and critique of forecasts of sockeye salmon returning to Bristol Bay, Alaska, in 1992. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 2A93-01, Anchorage.

Cross, B. A., B. L. Stratton, and D. L. Crawford. 1994. A synopsis and critique of forecasts of sockeye salmon returning to Bristol Bay in 1993. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 2A94-04, Anchorage.

LITERATURE CITED (Continued)

Eggers, D. M. and A. R. Shaul. 1987. Assessment of Bristol Bay sockeye salmon run strength based on in-season performance of the South Peninsula June interception fishery. Alaska Department of Fish and Game, Division of Commercial Fisheries, Informational Leaflet 264, Juneau.

Eggers, D. M., C. P. Meacham, and D. C. Huttunen. 1984. Population dynamics of Bristol Bay sockeye salmon, 1956-1983. Pages 200-225 *in* W. G. Pearcy, editor. The influence of ocean conditions on the production of salmonids in the North Pacific. Oregon State University, Sea Grant College Program, ORESU-W-83-001, Corvallis.

Eggers, D. M., C. P. Meacham, and H. Yuen. 1983a. Synopsis and critique of the available forecasts of sockeye salmon returning to Bristol Bay in 1983. Alaska Department of Fish and Game, Division of Commercial Fisheries, Informational Leaflet 207, Juneau.

Eggers, D. M., C. P. Meacham, and H. Yuen. 1983b. Synopsis and critique of the available forecasts of sockeye salmon (*Oncorhynchus nerka*) returning to Bristol Bay in 1984. Alaska Department of Fish and Game, Division of Commercial Fisheries, Informational Leaflet 228, Juneau.

Fried, S. M. and B. A. Cross. 1988. A synopsis and critique of forecasts of sockeye salmon returning to Bristol Bay, Alaska in 1989. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 2A88-13, Anchorage.

Fried, S. M. and B. A. Cross. 1990. A synopsis and critique of forecasts of sockeye salmon returning to Bristol Bay, Alaska in 1990. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 2K90-01, Anchorage.

Fried, S. M. and R. Hilborn. 1988. Inseason forecasting of Bristol Bay, Alaska, sockeye salmon (*Oncorhynchus nerka*) abundance using Bayesian probability theory. Canadian Journal of Fisheries and Aquatic Sciences, 45: 850-855.

Fried, S. M. and H. J. Yuen. 1985. A synopsis and critique of forecasts of sockeye salmon (*Oncorhynchus nerka*) returning to Bristol Bay in 1985. Alaska Department of Fish and Game, Division of Commercial Fisheries, Informational Leaflet 247, Juneau.

Fried, S. M. and H. J. Yuen. 1986. A synopsis and critique of forecasts of sockeye salmon (*Oncorhynchus nerka*) returning to Bristol Bay in 1986. Alaska Department of Fish and Game, Division of Commercial Fisheries, Informational Leaflet 255, Juneau.

Fried, S. M. and H. J. Yuen. 1987. A synopsis and critique of forecasts of sockeye salmon (*Oncorhynchus nerka*) returning to Bristol Bay in 1987. Alaska Department of Fish and Game, Division of Commercial Fisheries, Fishery Research Bulletin 87-01, Juneau.

Fried, S.M., B.A. Cross, and H.J. Yuen. 1988. A synopsis and critique of forecasts of sockeye salmon returning to Bristol Bay, Alaska in 1988. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Fishery Report 88-05, Juneau.

Fried, S. M., H. J. Yuen, and B. G. Bue. 1987. Naknek, Egegik, and Ugashik Rivers sockeye salmon smolt studies for 1983. Pages 36-71, *in* B. G. Bue and S. M. Fried, editors. Bristol Bay sockeye salmon smolt studies for 1983. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Data Report 207, Juneau.

Koo, T. S. Y. 1962. Age designation in salmon. Pages 37-48 *in* T. S. Y. Koo, editor. Studies of Alaska red salmon. University of Washington Publications in Fisheries, New Series, Volume I, Seattle.

Mathisen, O. A. and P.H. Poe. 1981. Sockeye salmon cycles in the Kvichak River, Bristol Bay, Alaska. Verhandlungen Internationale Verein Limnologie 21: 1207-1213.

Peterman, R. M. 1982a. Nonlinear relation between smolts and adults in Babine Lake sockeye salmon (*Oncorhynchus nerka*) and implications for other salmon populations. Canadian Journal of Fisheries and Aquatic Sciences 39:904-913.

Peterman, R. M. 1982b. Model of salmon age structure and its use in preseason forecasting and studies of marine survival. Canadian Journal of Fisheries and Aquatic Sciences 39: 1444-1452.

Ricker, W. E. 1954. Stock and recruitment. Journal of the Fisheries Research Board of Canada 11: 559-623.

Russell, P. A. 1972. 1971 Kvichak River sockeye salmon smolt studies. Pages 1-28 *in* P. A. Russell and M. L. McCurdy editors. 1971 Bristol Bay sockeye salmon smolt studies. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Data Report 2, Juneau.

Snedecor, G. W. and W. G. Cochran. 1969. Statistical Methods. Sixth Edition. Iowa State University Press, Ames.

Stratton, B. L., D. L. Crawford. *In press*. Abundance, age, sex, and size statistics for Pacific salmon in Bristol Bay, 1992. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Fishery Report, Juneau.

Yuen, H.J. and S.M. Fried. 1985. 1984 Port Moller offshore test fishing. Pages 1-26, *in* S. M. Fried, editor. 1984 Bristol Bay Pacific salmon test fishing projects. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Data Report 154, Juneau.

Table 1. Comparison of preliminary forecasts, estimated forecast errors, and adjusted forecasts for 1994 combined eastside, combined westside, and individual Bristol Bay rivers.

		Millions of Sockeye Salmon		
Data Base	Method of Modeling	Original 1994 Forecast	Estimated Error 1994[a]	Adjusted 1994 Forecast
Eastside[b] - All Data	Linear Regress	29.0	-22.0	51.0
Eastside - All Data	Poly Regress	29.0	-25.4	54.4
Eastside - Recent Data	84-93 Avg Error	35.4	-13.3	48.7
Westside[c] - All Data	Linear Regress	3.2	-2.5	5.7
Westside - All Data	Poly Regress	3.2	-1.5	4.7
Westside - All Data	84-93 Avg Error	3.2	-1.3	4.5
Westside - Recent Data	84-93 Avg Error	5.3	+0.6	4.6
Individual Rivers -	84-93 Avg Error			
Eastside- Recent Data				
Kvichak		14.6	-4.4	19.0
Branch		0.4	-0.1	0.5
Naknek		3.3	-0.8	4.1
Egegik		12.5	-7.6	20.1
Ugashik		4.5	-1.5	6.0
Eastside Total		35.4	-14.4	49.8
Westside- All Data				
Wood		2.0	-0.5	2.5
Igushik		0.8	-0.8	1.6
Nushagak		1.6	0.0	1.6
Togiak		0.4	-0.2	0.6
Westside Total		4.8	-1.5	6.3

[a] Error = (predicted - actual).
[b] Eastside includes Kvichak, Naknek, Egegik, and Ugashik Rivers.
[c] Westside includes Wood, Igushik, and Togiak Rivers.

Table 2. Forecasted production, spawning escapement goals, and total projected harvests of major age classes of sockeye salmon returning to Bristol Bay river systems in 1994 based on results of the Mixed Data method adjusted by individual rivers 1984-93 average percent error.

	Thousands of Sockeye Salmon							
	Forecasted Production by Age Class							
District: River	1.2	2.2	1.3	2.3	Other[a]	Total	Spawning Goal	Total Harvest
NAKNEK-KVICHAK:								
Kvichak	3,311	12,610	2,159	920		19,000	8,000	11,000
Branch	249	52	199	24		524	185	339
Naknek	928	828	1,350	1,037		4,143	1,000	3,143
Total	4,488	13,490	3,708	1,981		23,667	9,185	14,482
EGEGIK	674	7,908	1,870	9,690		20,142	1,000	19,142
UGASHIK	955	2,586	1,565	850		5,956	700	5,256
NUSHAGAK:[b]								
Wood	980	127	1,336	68		2,511	1,000	1,511
Igushik	238	87	1,184	66		1,575	200	1,375
Nushagak	131	22	794	14	626	1,587	550	1,037
Total	1,349	236	3,314	148	626	5,673	1,750	3,923
TOGIAK[c]	153	32	328	40		553	150	403
BRISTOL BAY	7,619	24,252	10,785	12,709	626	55,991	12,785	43,206

[a] Other includes zero freshwater ages (0.2, 0.3, 0.4) which are only forecasted for Nushagak River.

[b] Forecast for Snake River system was not included (1971-1991 average escapement was 18,000).

[c] Forecasts for Kulukak, Kanik, Osviak, and Matogak River systems were not included. These systems may contribute an additional 77,000 (1984-1993 mean catch) to Togiak District harvest.

Table 3. Projected commercial harvests of sockeye salmon returning to Bristol Bay river systems in 1994 based on results of the Mixed Data method adjusted by individual rivers 1984-93 average percent error.

District: River	Forecasted Total Production	Shumagin Islands-S. Unimak Harvest[a]	Bristol Bay Total Run	Bristol Bay Spawning Goal	Bristol Bay Harvest
	Thousands of Sockeye Salmon				
NAKNEK-KVICHAK:					
Kvichak	19,000	1,217	17,783	8,000	9,783
Branch	524	34	490	185	305
Naknek	4,143	265	3,878	1,000	2,878
Total	23,667	1,516	22,151	9,185	12,966
EGEGIK	20,142	1,290	18,852	1,000	17,852
UGASHIK	5,956	381	5,575	700	4,875
NUSHAGAK:					
Wood	2,511	161	2,350	1,000	1,350
Igushik	1,575	101	1,474	200	1,274
Nushagak	1,587	102	1,485	550	935
Total	5,673	363	5,310	1,750	3,560
TOGIAK	553	35	518	150	368
BRISTOL BAY	55,991	3,586	52,405	12,785	39,620

[a] Guideline harvest calculated as 8.3% of projected Bristol Bay harvest. Numbers were apportioned among river systems based on proportions in the forecast of total production.

Table 4. Preliminary forecasts of sockeye salmon returns to Bristol Bay, 1994-1997, based on spawner-recruit data only, and not adjusted for historic forecast errors.

DISTRICT: River	Thousands of Sockeye Salmon			
	1994	1995	1996	1997
NAKNEK-KVICHAK:				
Kvichak	14,668	13,237	9,483	9,671
Branch	433	438	385	386
Naknek	3,572	5,303	6,905	5,016
Total	18,673	18,978	16,773	15,073
EGEGIK	11,227	8,136	9,064	9,914
UGASHIK	5,241	4,536	7,535	7,280
NUSHAGAK:				
Wood	2,110	2,159	2,281	2,223
Igushik	764	738	701	730
Nushagak-Mulchatna	1,650	1,648	1,673	1,743
Total	4,524	4,545	4,655	4,696
TOGIAK	354	441	522	469
BRISTOL BAY	40,019	36,636	38,549	37,432

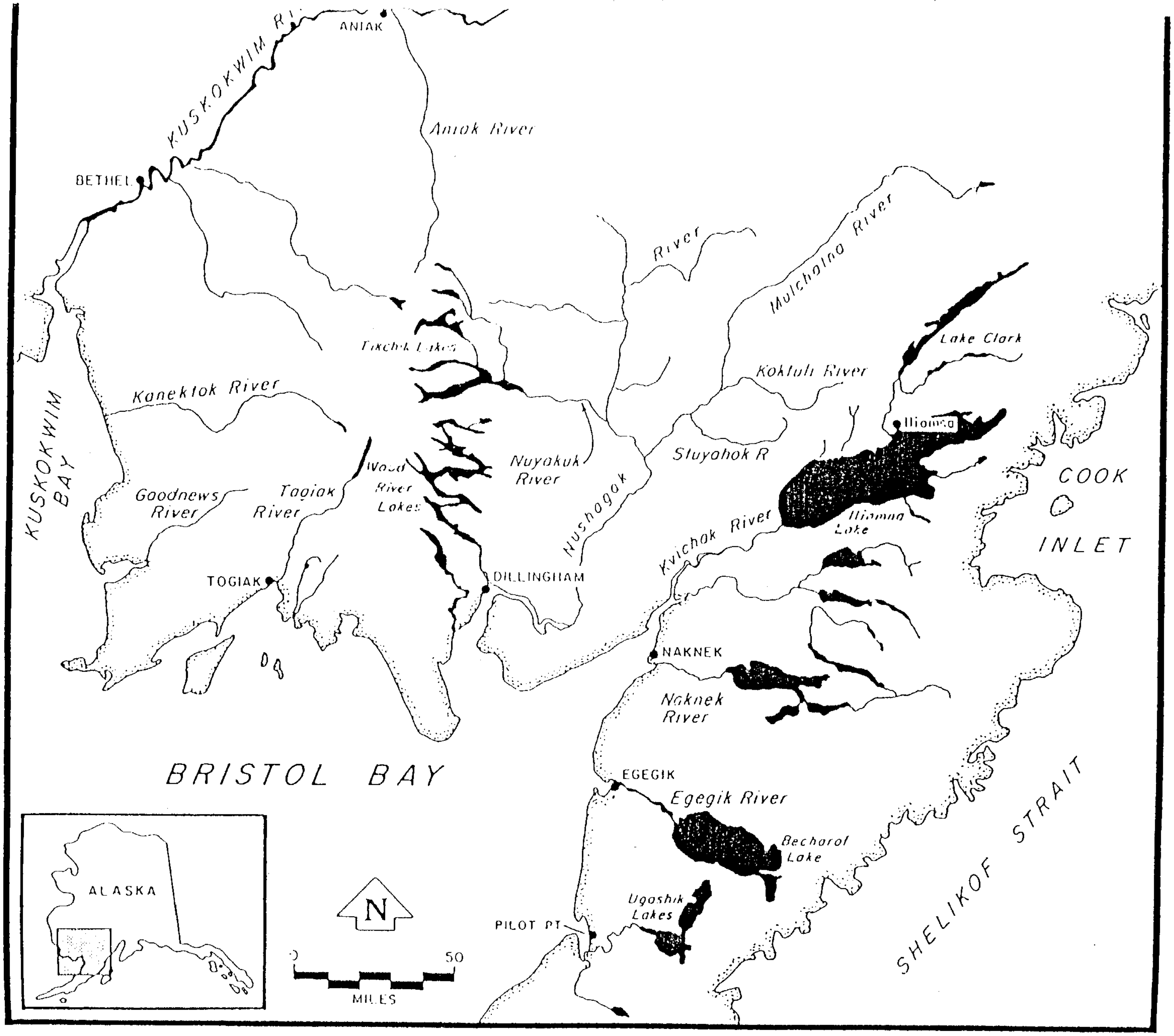


Figure 1. Map of Bristol Bay, Alaska showing major rivers.

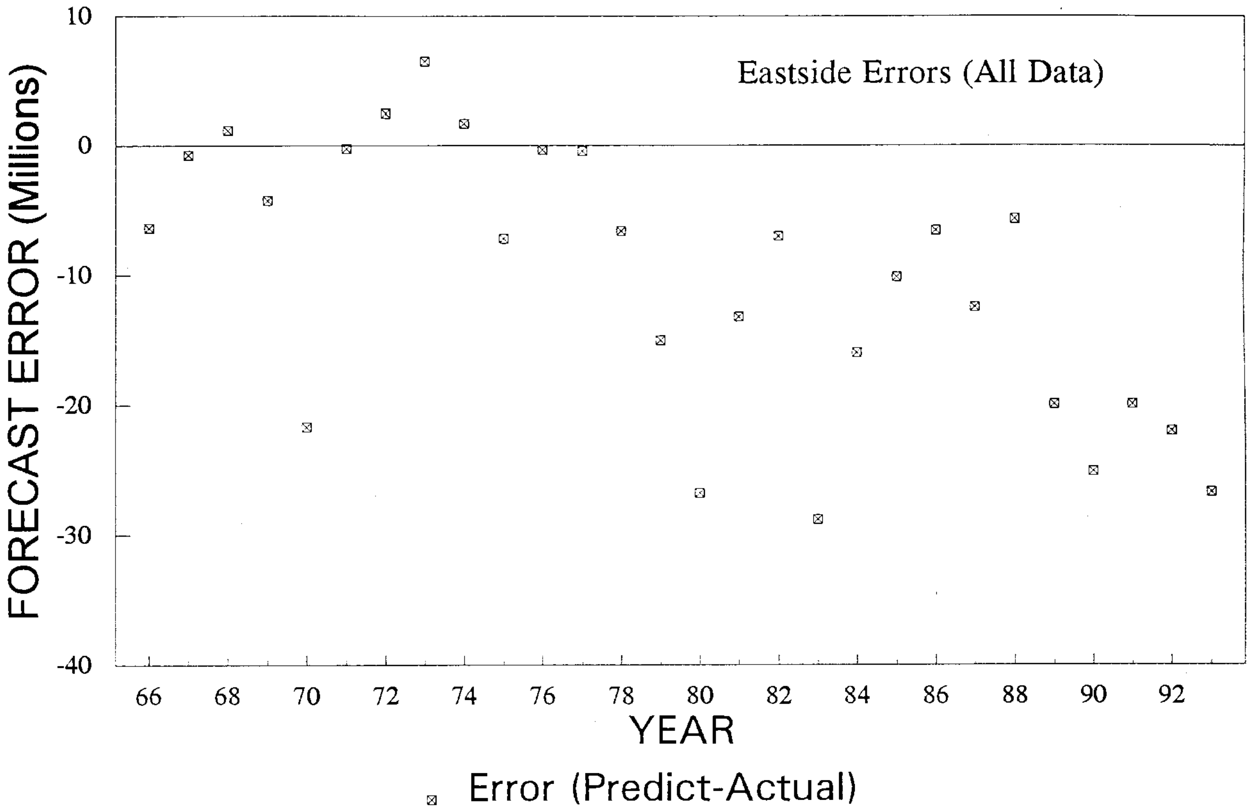


Figure 2. Errors (predicted run - actual run) of combined eastside Bristol Bay forecasts made with All Data for 1966-93.

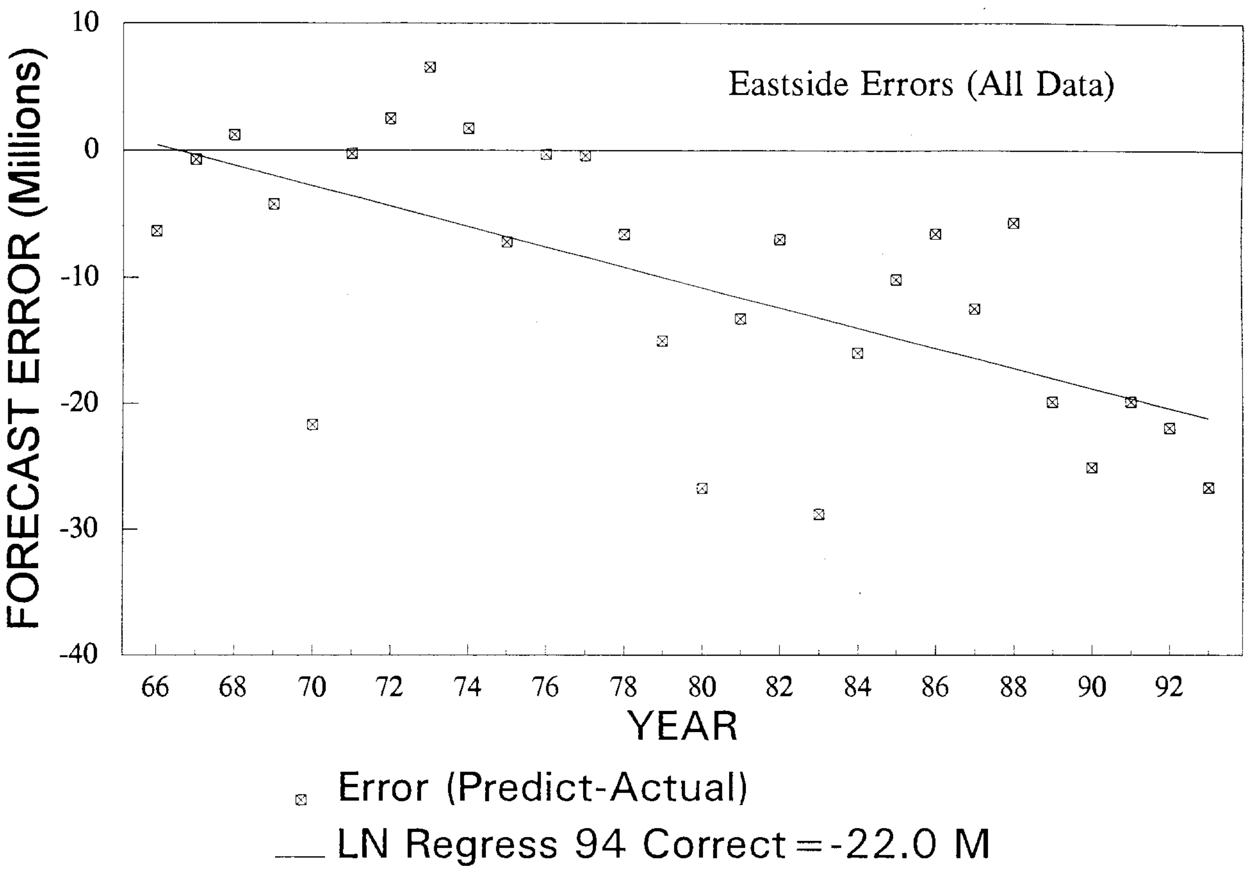


Figure 3. Linear regression model of errors (predicted run - actual run) of combined eastside Bristol Bay forecasts made with All Data for 1966-93.

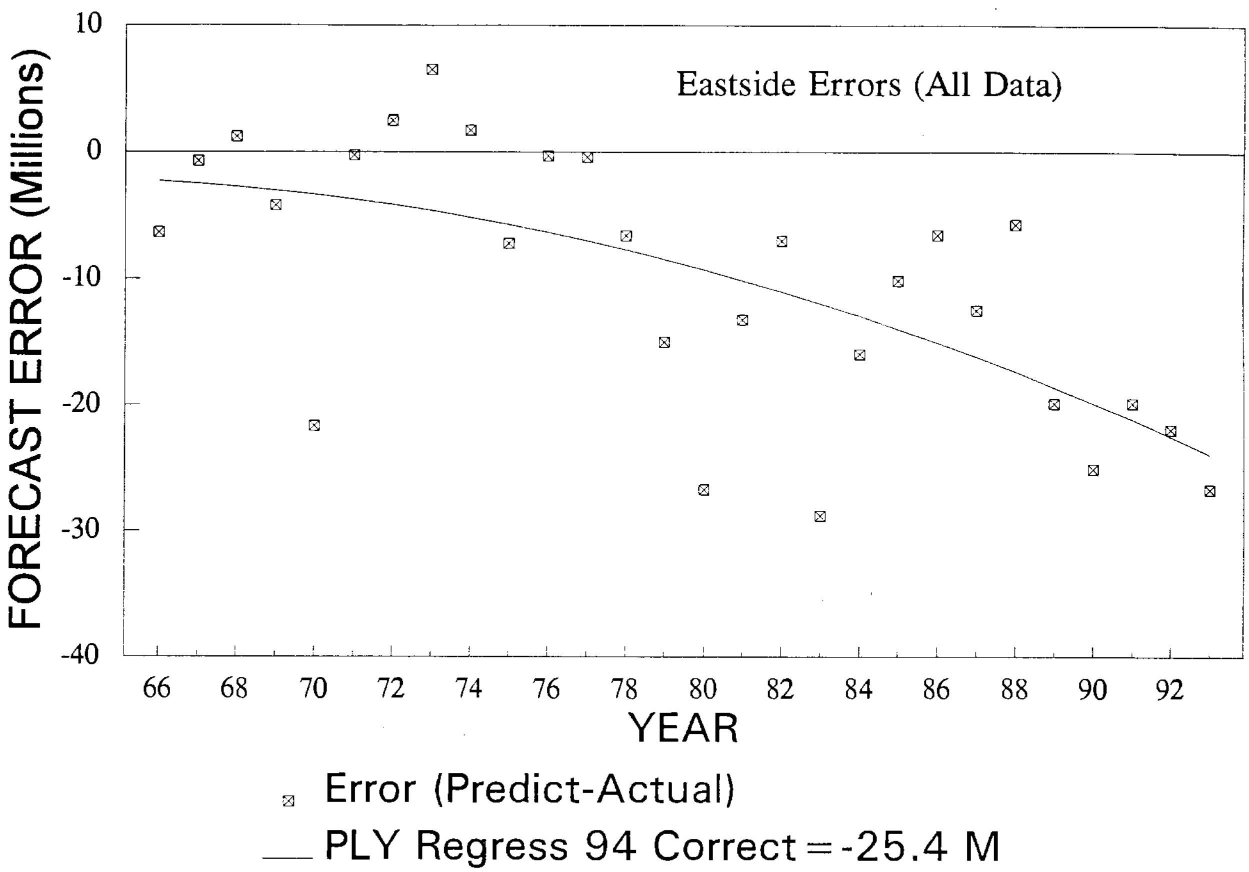


Figure 4. Polynomial regression model of errors (predicted run - actual run) of combined eastside Bristol Bay forecasts made with All Data for 1966-93.

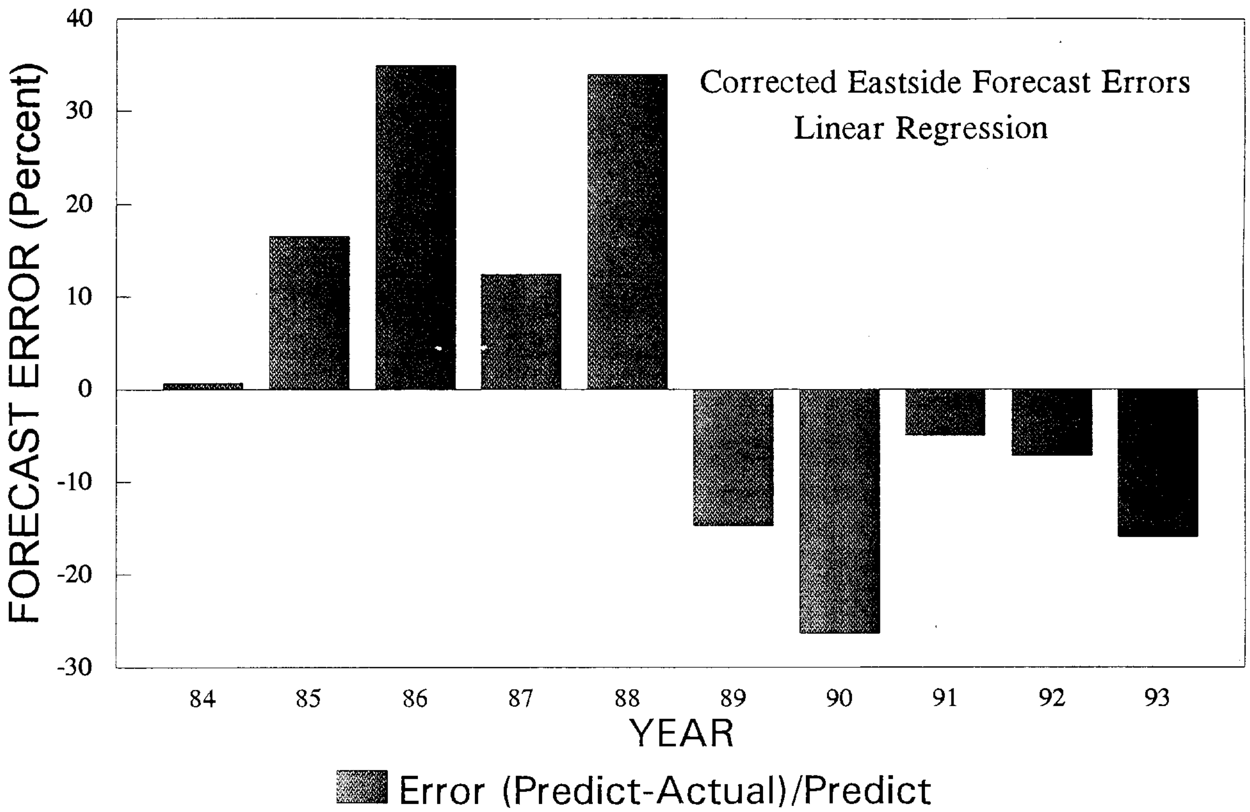


Figure 5. Errors (predicted run - actual run) of combined eastside Bristol Bay forecasts made with All Data and adjusted with an estimate of error from linear regression model, 1984-93.

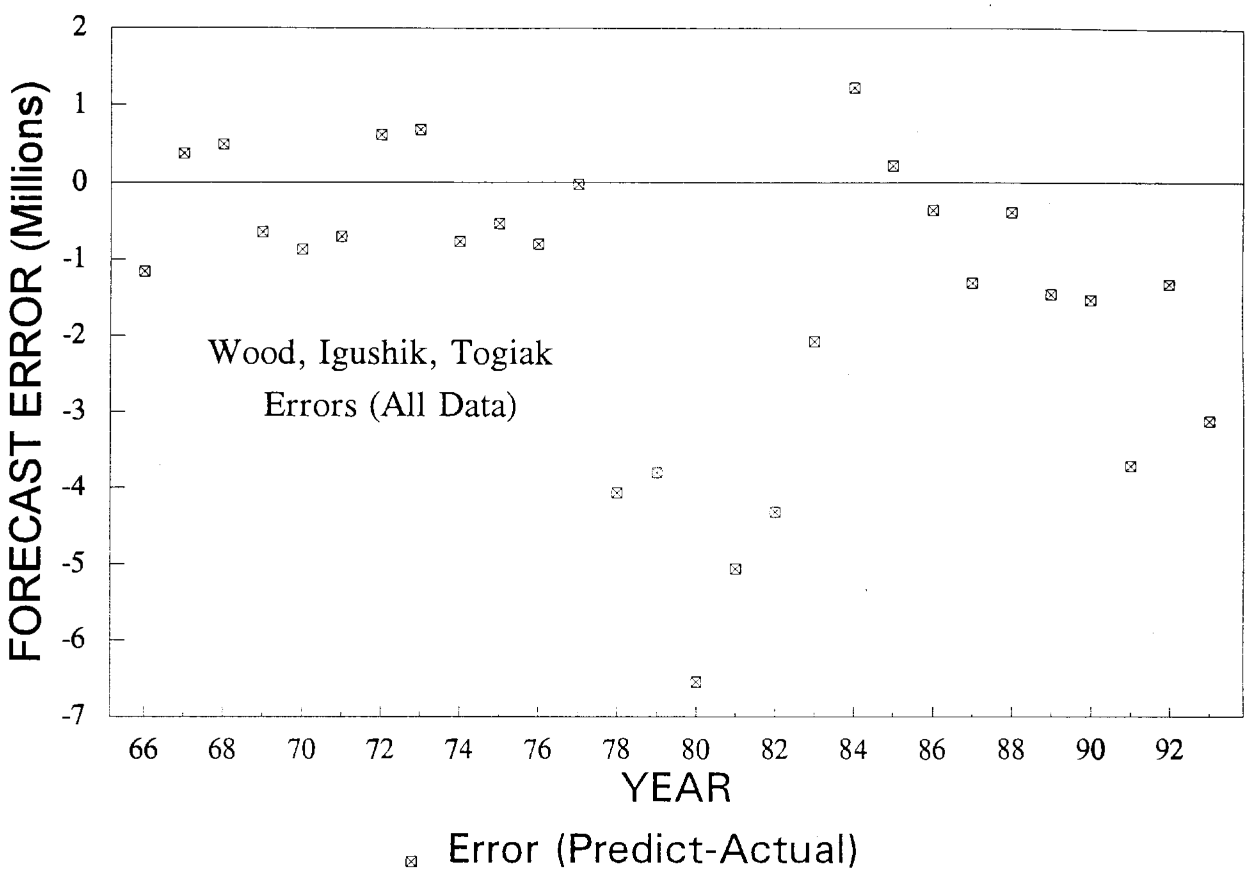


Figure 6. Errors (predicted run - actual run) of combined westside Bristol Bay forecasts made with All Data for 1966-93.

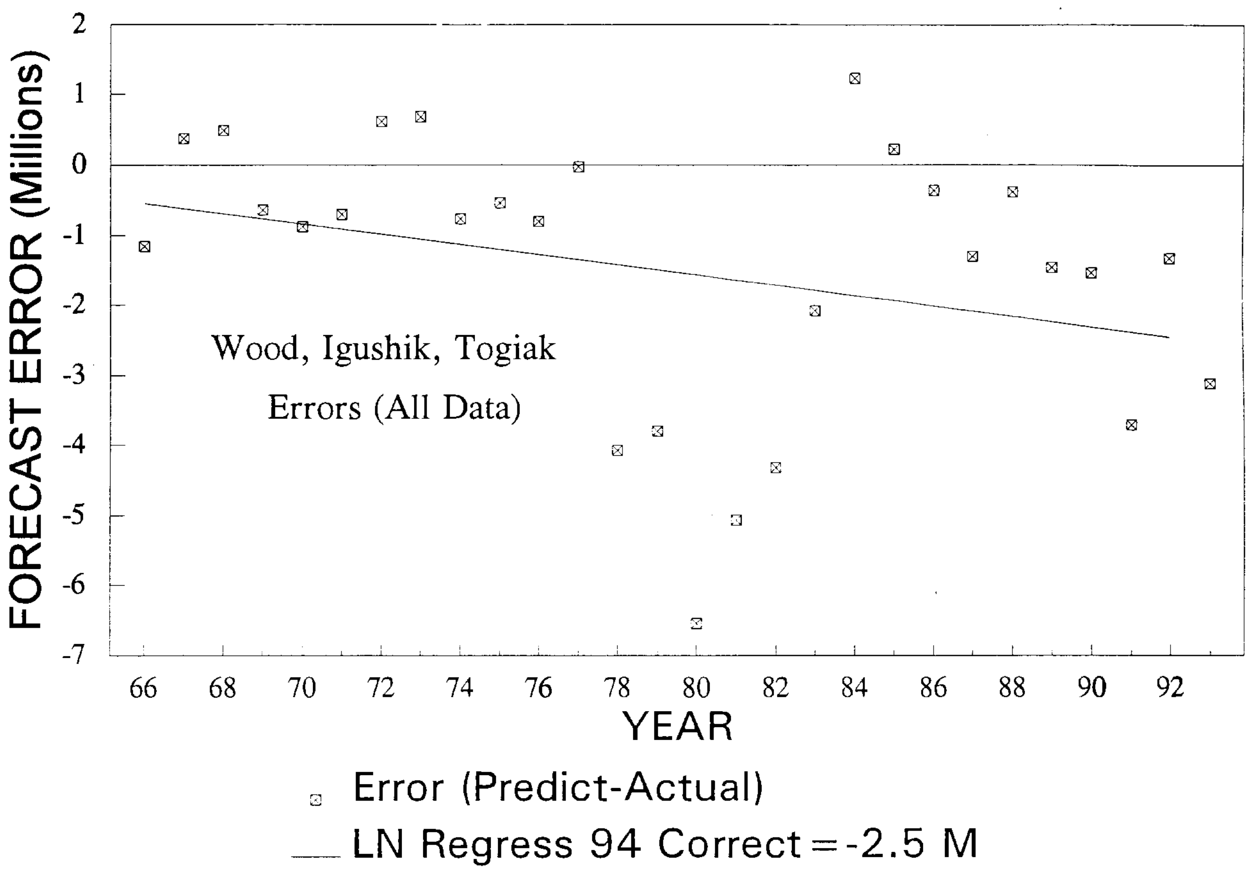


Figure 7. Linear regression model of errors (predicted run - actual run) of combined westside Bristol Bay forecasts made with All Data for 1966-93.

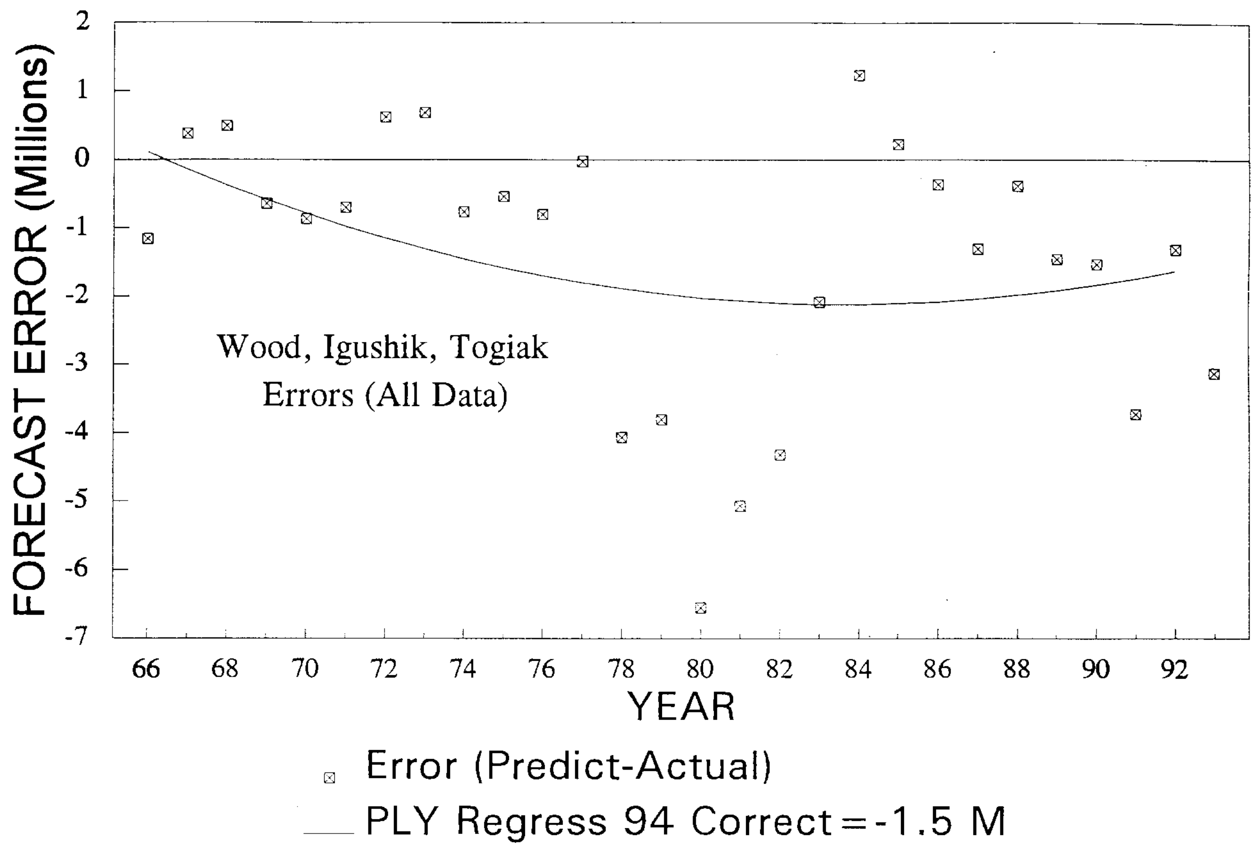
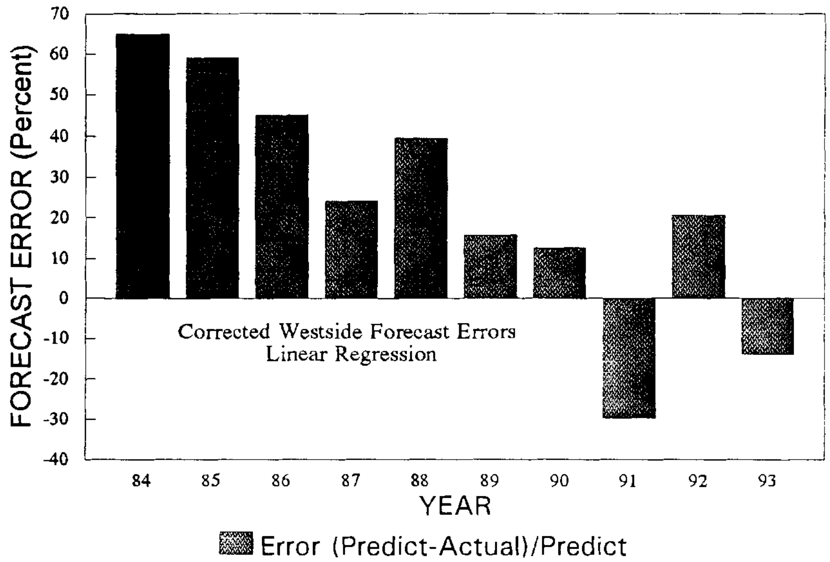


Figure 8. Polynomial regression model of errors (predicted run - actual run) of combined westside Bristol Bay forecasts made with All Data for 1966-93.



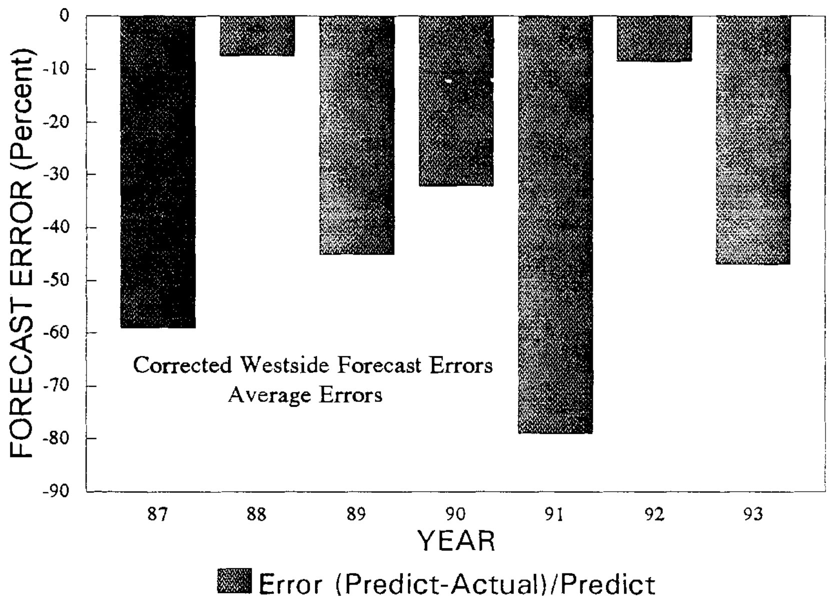
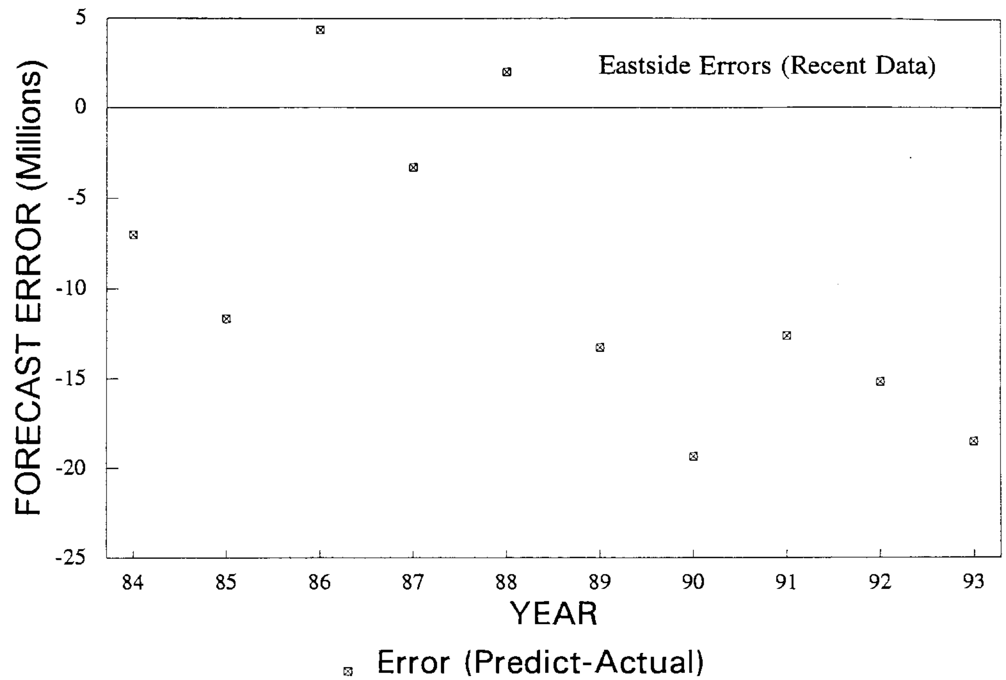


Figure 9. Errors (predicted run - actual run) of combined westside Bristol Bay forecasts made with All Data and adjusted with an estimate of error from linear regression model, 1984-93 (top) and adjusted with average percent error, 1987-93 (bottom).



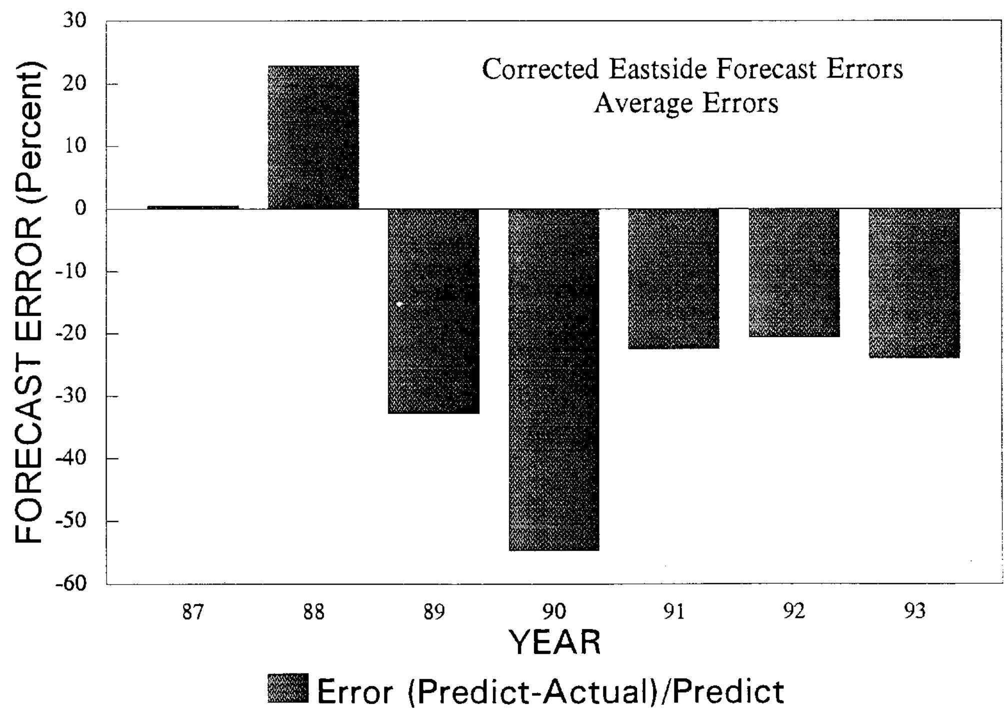
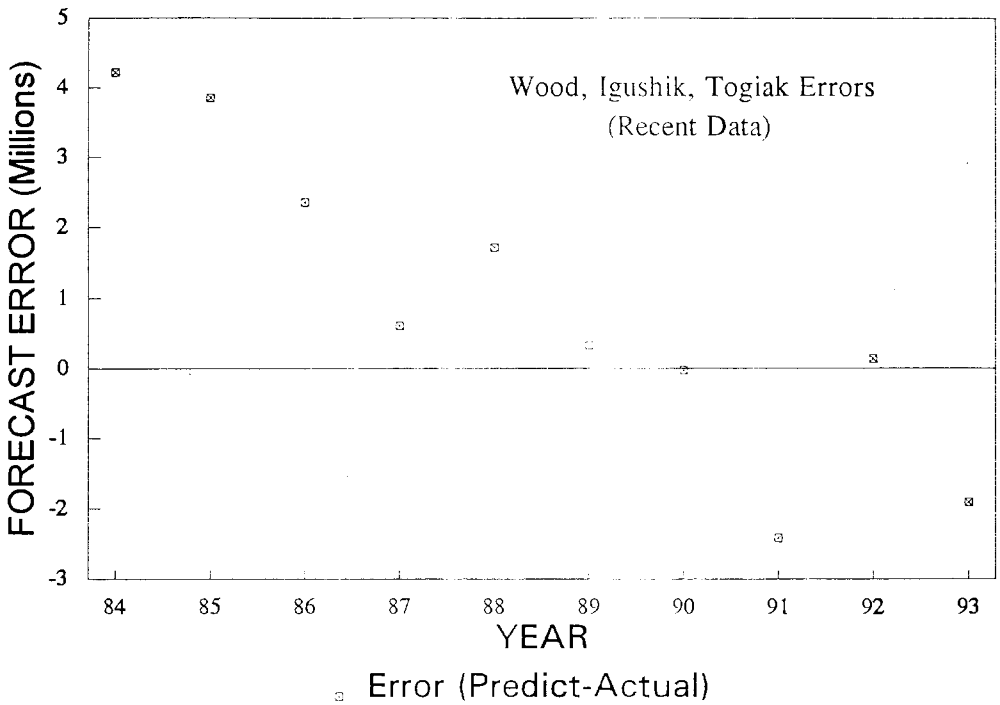


Figure 10. Errors (predicted run - actual run) of combined eastside Bristol Bay forecasts made with Recent Data for 1984-93 (top) and adjusted with the average percent error, 1987-93 (bottom).



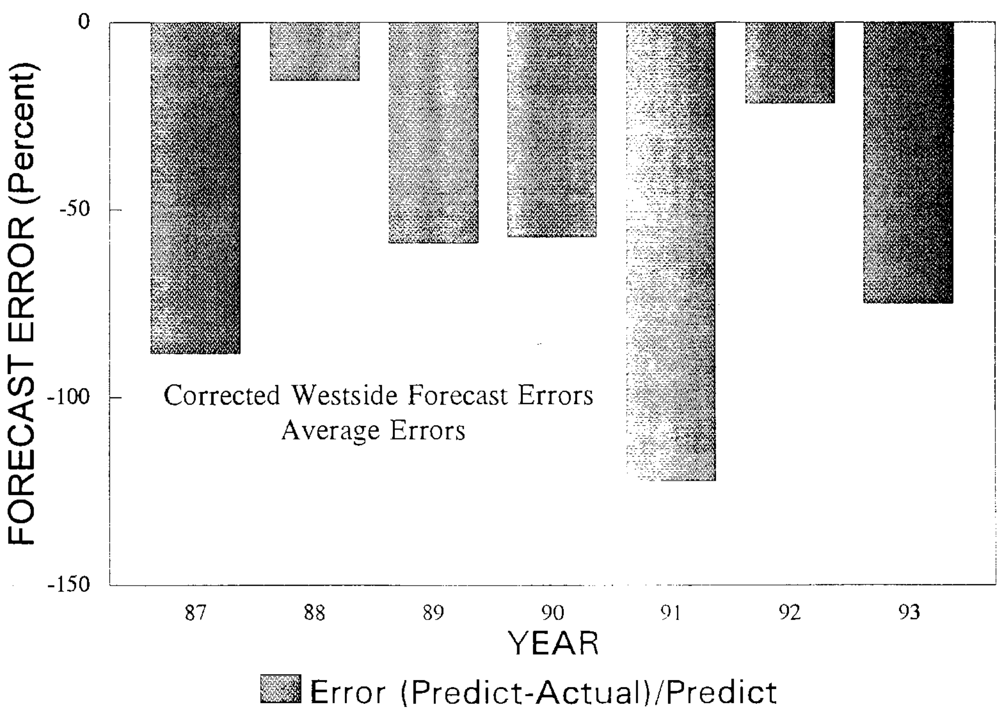


Figure 11. Errors (predicted run - actual run) of combined westside Bristol Bay forecasts made with Recent Data for 1984-93 (top) and adjusted with average percent error, 1987-93 (bottom).

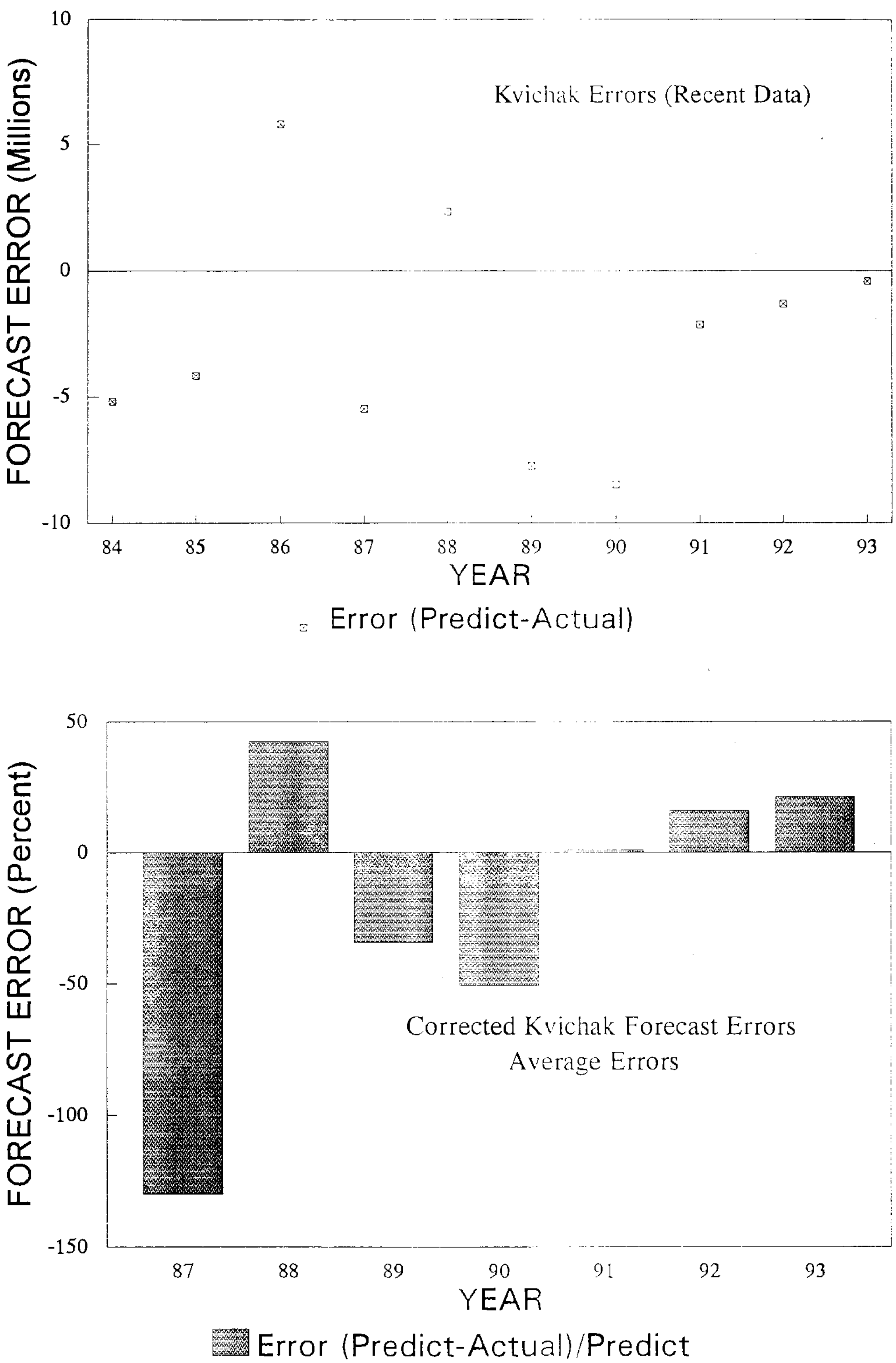
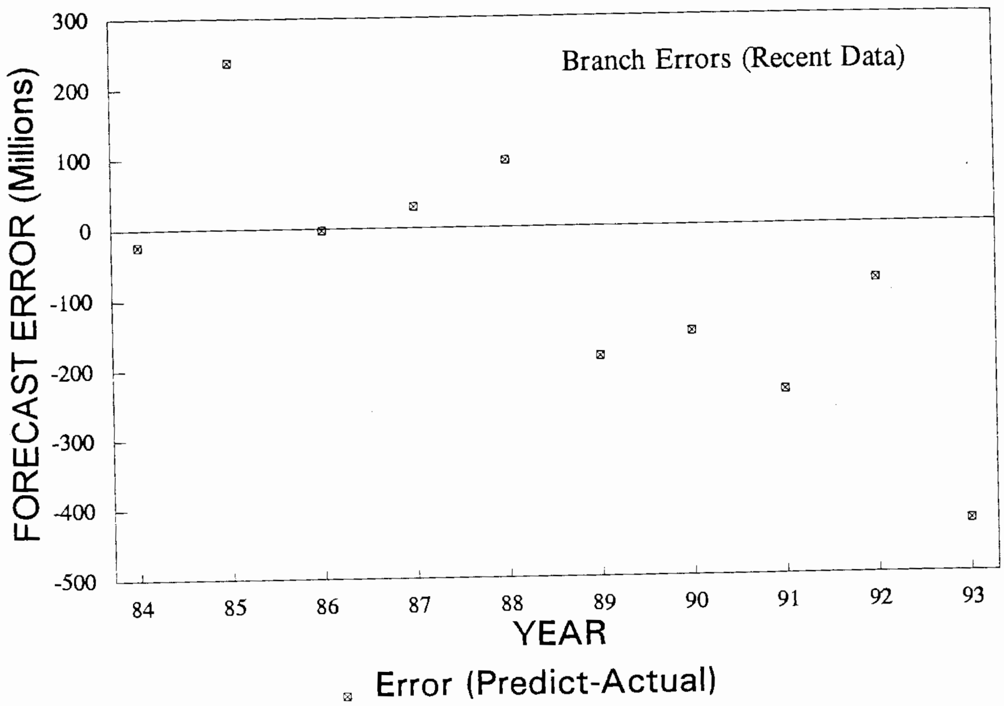


Figure 12. Errors (predicted run - actual run) of Kvichak River forecasts made with Recent Data for 1984-93 (top) and adjusted with the average percent error, 1987-93 (bottom).



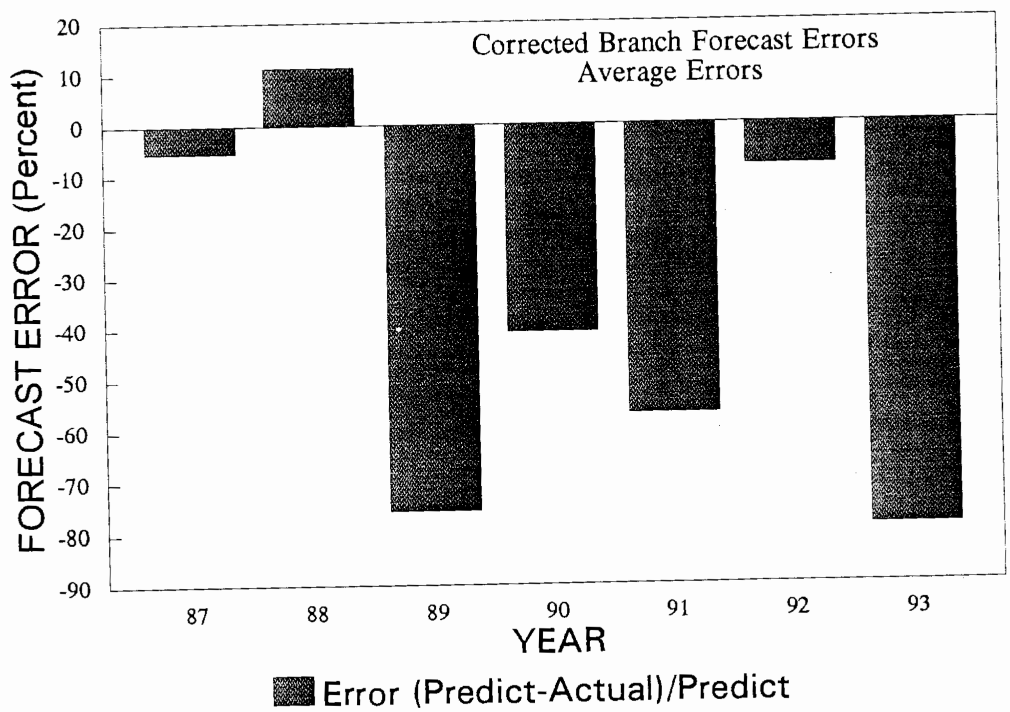
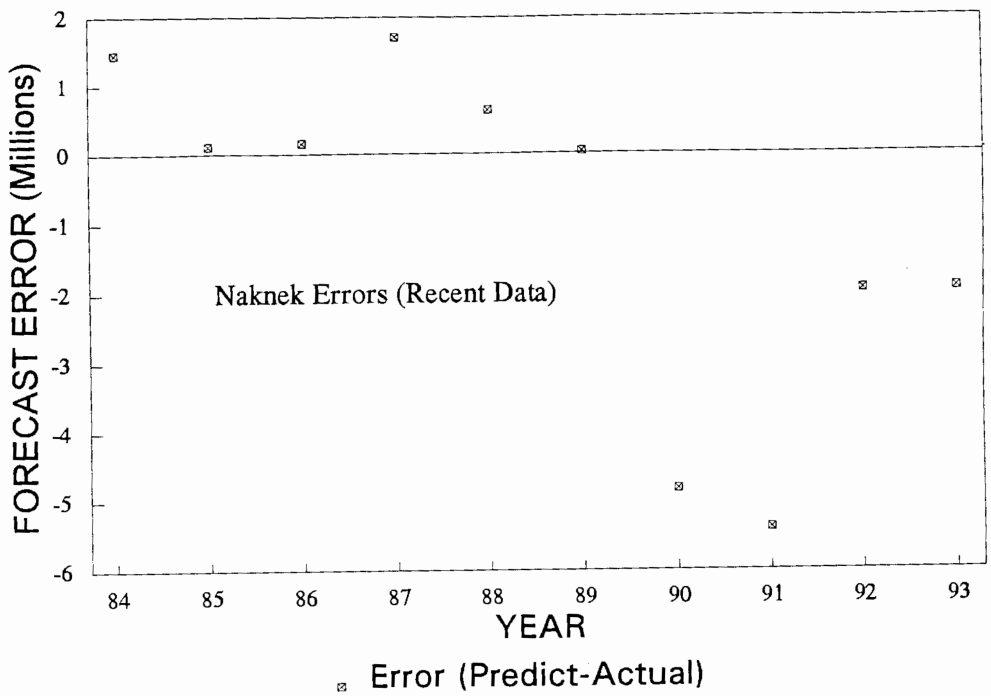


Figure 13. Errors (predicted run - actual run) of Branch River forecasts made with Recent Data for 1984-93 (top) and adjusted with the average percent error, 1987-93 (bottom).



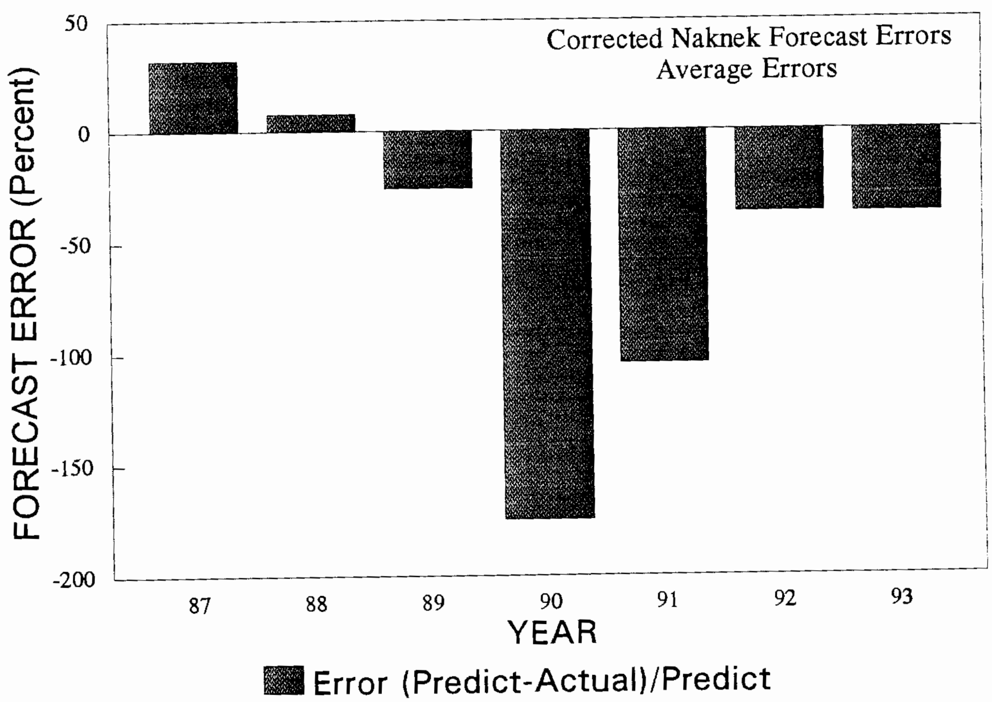
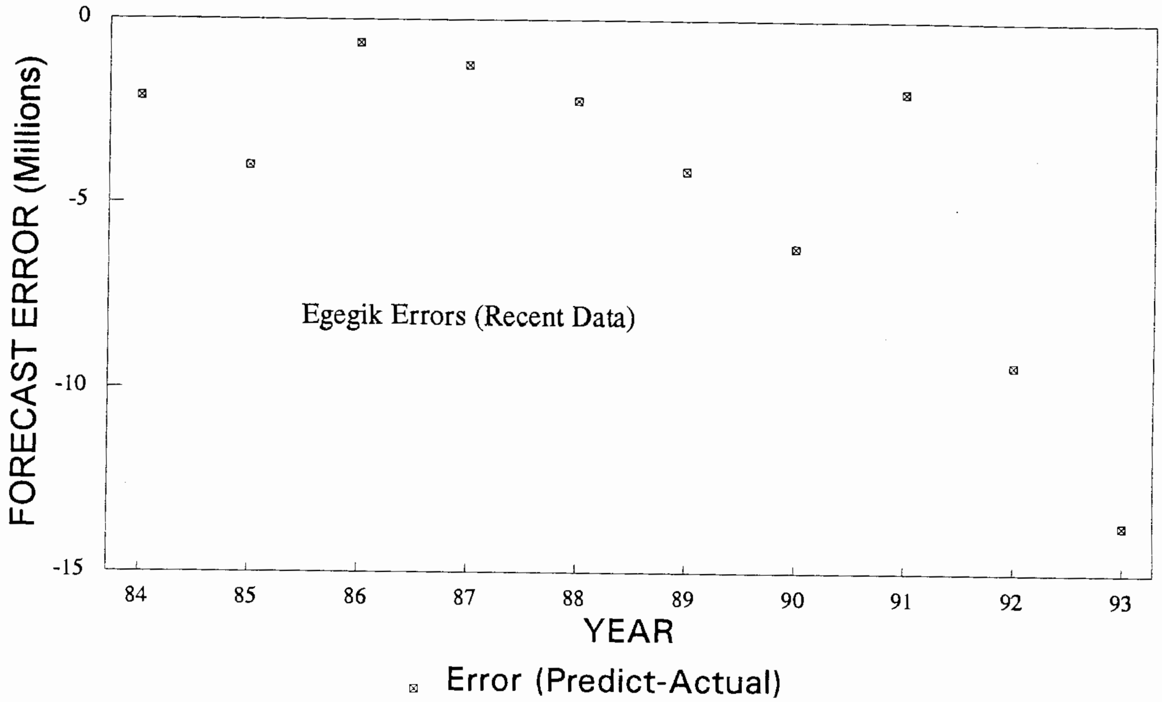


Figure 14. Errors (predicted run - actual run) of Naknek River forecasts made with Recent Data for 1984-93 (top) and adjusted with the average percent error, 1987-93 (bottom).



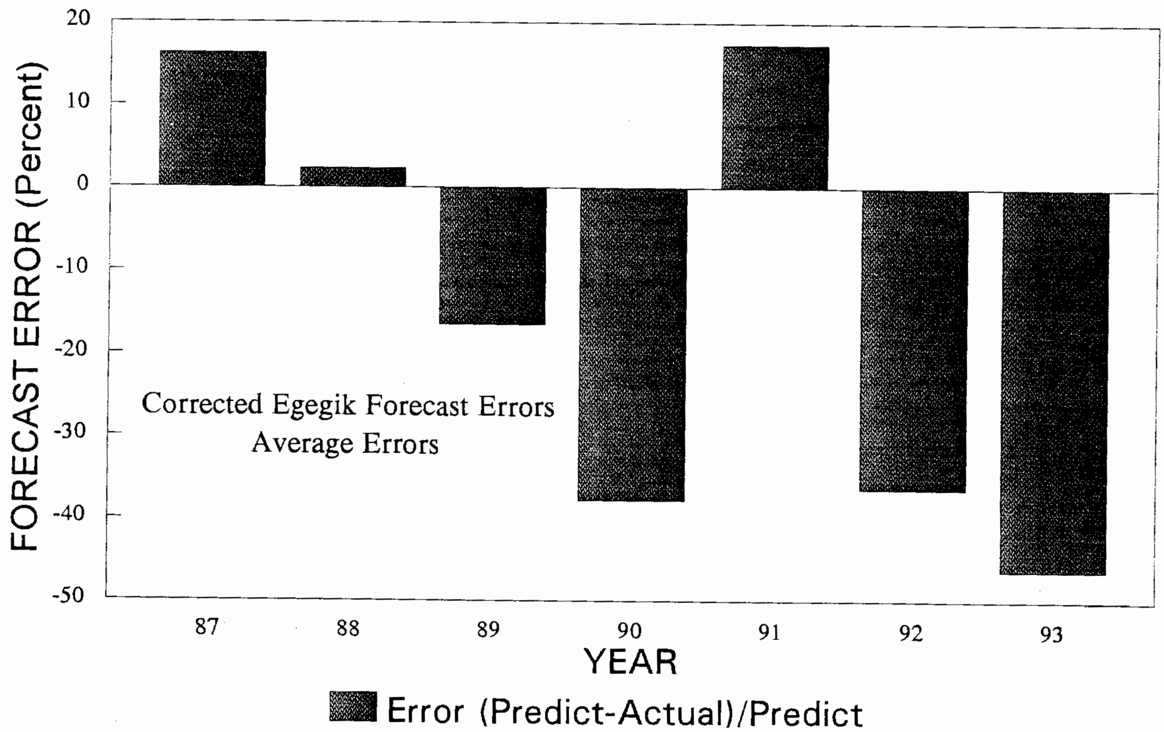
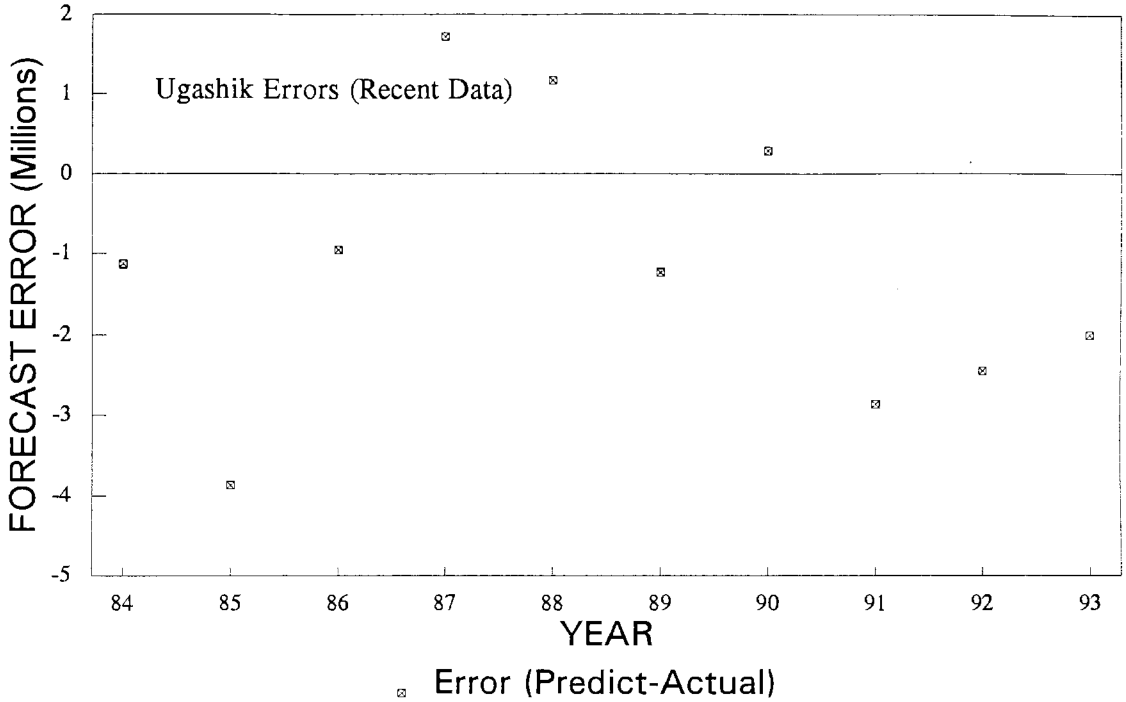


Figure 15. Errors (predicted run - actual run) of Egegik River forecasts made with Recent Data for 1984-93 (top) and adjusted with the average



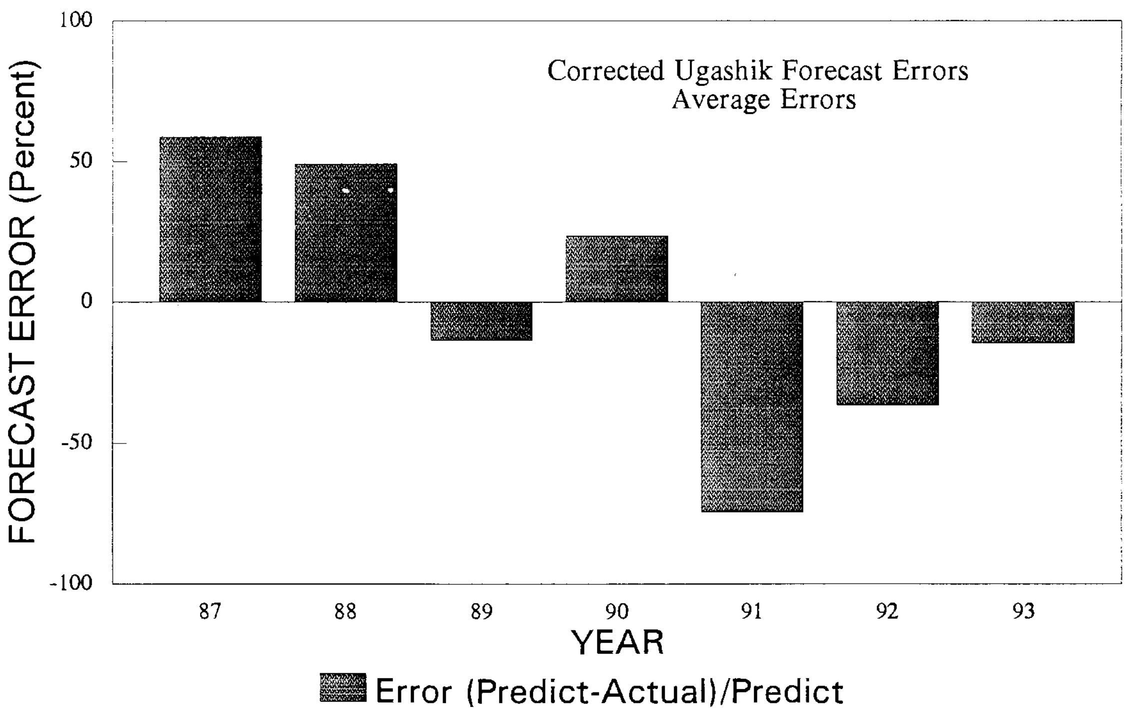
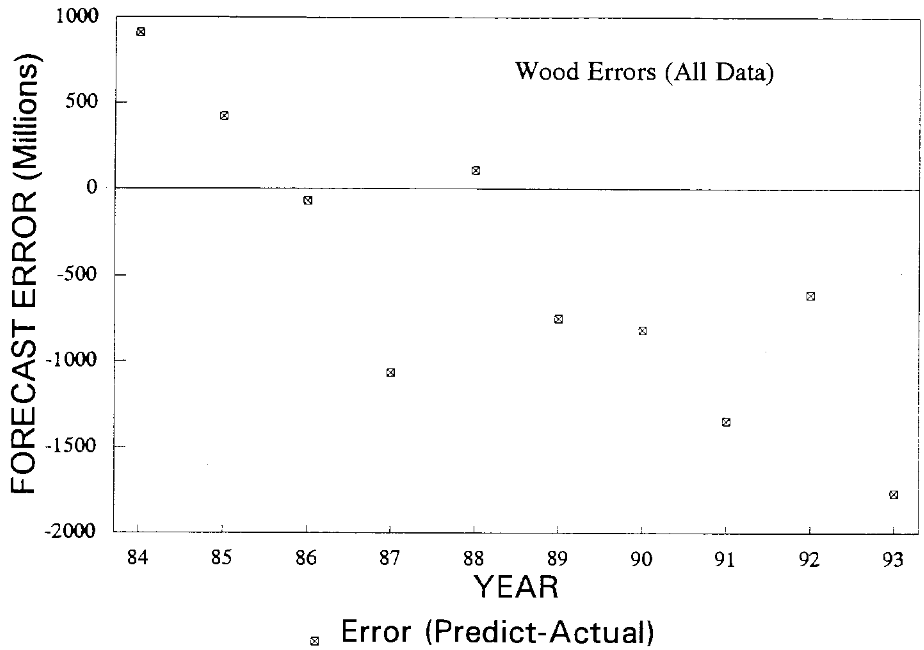


Figure 16. Errors (predicted run - actual run) of Ugashik River forecasts made made with Recent Data for 1984-93 (top) and adjusted with the average percent error, 1987-93 (bottom).



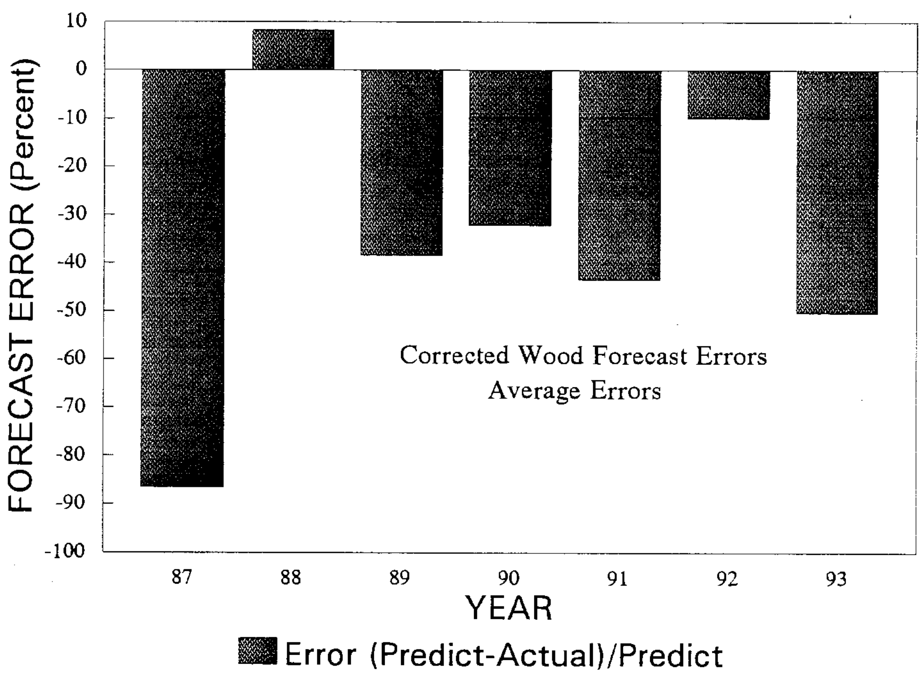
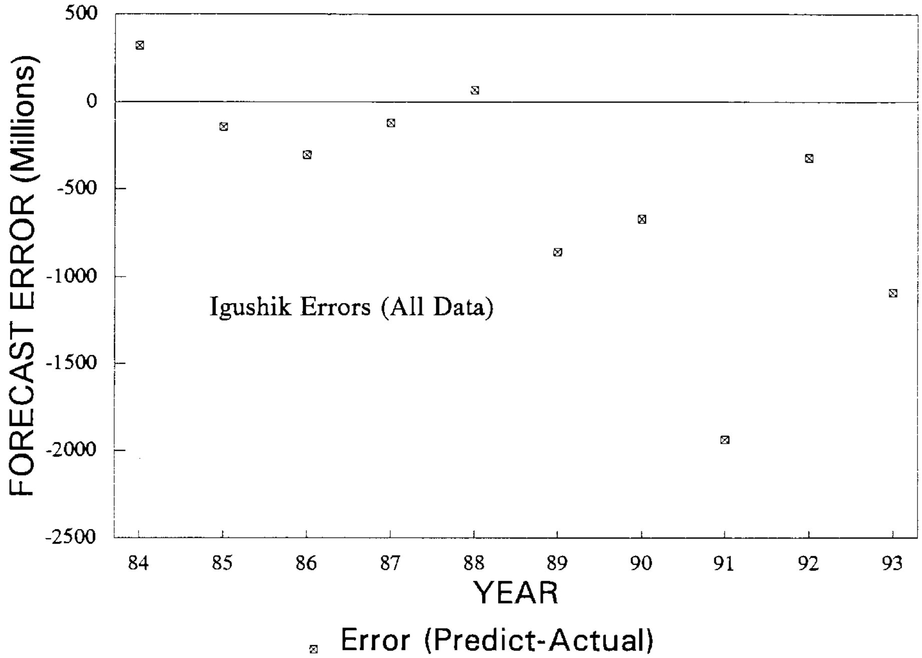


Figure 17. Errors (predicted run - actual run) of Wood River forecasts made with All Data for 1984-93 (top) and adjusted with the average percent error, 1987-93 (bottom).



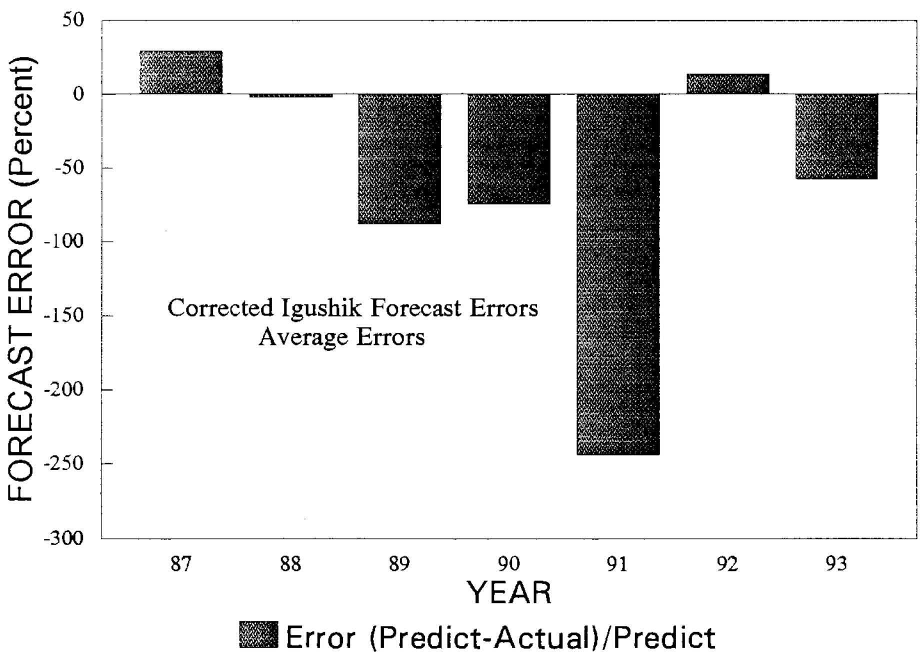
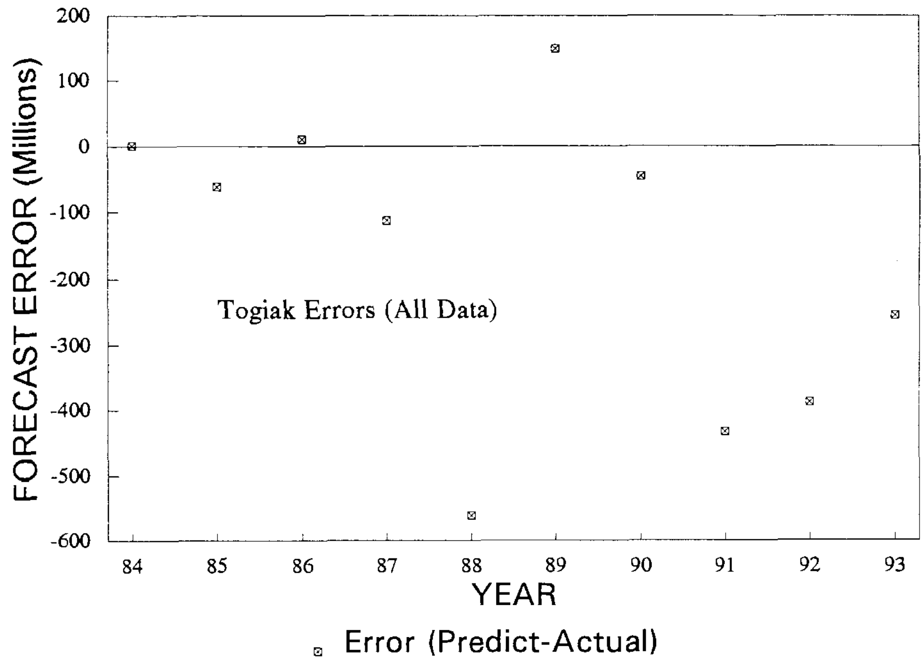


Figure 18. Errors (predicted run - actual run) of Igushik River forecasts made with All Data for 1984-93 (top) and adjusted with the average percent error, 1987-93 (bottom).



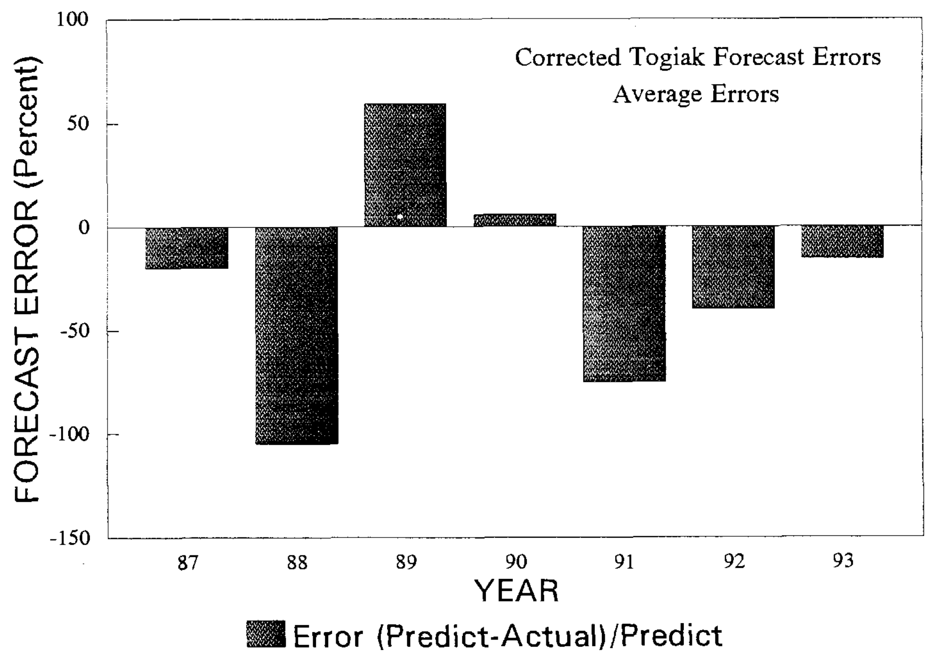


Figure 19. Errors (predicted run - actual run) of Togiak River forecasts made with All Data for 1984-93 (top) and adjusted with the average percent error, 1987-93 (bottom).

APPENDIX A: HISTORIC SOCKEYE FORECASTS AND RETURNS

Appendix A.1. Preseason forecasts of sockeye salmon returns to Bristol Bay, 1961–1993, issued by the Alaska Department of Fish and Game.

Year	Forecast (millions)	Actual Return (millions)		Percent Error[b]
		Inshore	Total[a]	
1961	43.6	18.1	24.5	78.0
1962	19.6	10.4	11.7	67.5
1963	8.6	6.9	8.0	7.5
1964	17.4	10.9	11.5	51.3
1965	27.8	53.1	60.8	–54.3
1966	31.3	17.5	20.0	56.5
1967	13.7	10.3	11.5	19.1
1968	10.4	8.0	9.4	10.6
1969	21.3	19.0	21.9	–2.7
1970	55.8	39.4	45.0	24.0
1971	15.2	15.8	18.3	–16.9
1972	9.7	5.4	7.2	34.7
1973	6.2	2.4	3.5	77.1
1974	5.0	10.9	11.5	–56.5
1975	12.0	24.2	25.8	–53.5
1976	12.0	11.5	12.8	–6.3
1977	8.4	9.7	10.7	–21.5
1978	11.5	19.8	20.8	–44.7
1979	22.7	39.8	40.9	–44.5
1980	54.5	62.4	66.2	–17.7
1981	26.7	34.5	37.1	–28.0
1982	34.6	22.1	24.7	40.1
1983	33.4	45.8	48.0	–30.4
1984	31.1	41.0	42.6	–27.0
1985	35.0	36.6	38.5	–9.1
1986	22.5	23.7	24.4	–7.8
1987	16.5	27.3	28.3	–41.7
1988	28.8	23.2	24.0	20.0
1989	30.4	43.9	45.7	–33.5
1990	26.7	47.6	49.0	–45.5
1991	31.9	42.2	43.8	–27.2
1992	39.6	45.1	47.5	–16.6
1993	44.7	52.1	55.0	–18.7

[a] Includes foreign high seas and domestic Shumagin Islands–South Unimak catches.

[b] Percent error calculated as:
(forecast – actual total return) / actual total return x 100.

APPENDIX B: HINDCAST ERRORS

Appendix B.1. Annual percent errors, mean percent errors (MPE), and mean absolute percent errors (MAPE) for hindcasts of total sockeye salmon returns to Bristol Bay river systems, 1984-93, based on All Data (1956-93) or Recent Data (1978-93).

	Percent Errors[a]											
Year	Kvichak	Branch	Naknek	Egegik	Ugashik	Wood	Igushik	Nuyakuk/ Nushagak[b]	Togiak	Combined East	Combined West	Total
					ALL DATA FORECASTS							
1984	-40.0	-32.7	-29.4	-49.1	-44.4	-12.2	73.5	23.9	0.4	-41.1	7.8	-36.5
1985	1.3	-9.5	-21.0	-58.9	-56.9	5.1	-33.5	-4.6	-20.5	-29.8	-5.7	-27.7
1986	126.3	-52.6	-32.0	-54.7	-67.8	-3.5	-36.2	-26.8	-4.4	-34.7	-18.1	-31.3
1987	-78.4	-13.4	-15.5	-43.0	-47.8	-35.0	-18.9	37.7	-24.0	-55.7	-22.0	-49.8
1988	-9.5	-13.0	13.5	-54.5	-17.0	9.9	13.5	42.3	-56.0	-27.3	-1.3	-23.0
1989	-48.5	-48.0	-18.4	-61.4	-47.4	-24.6	-64.5	-37.0	81.0	-49.4	-33.5	-47.5
1990	-55.6	-47.6	-65.1	-61.5	-50.2	-29.6	-51.1	-52.2	-11.9	-58.8	-39.6	-56.3
1991	-49.1	-49.2	-68.1	-41.1	-75.9	-38.0	-75.9	-34.8	-52.3	-56.8	-49.7	-55.4
1992	-27.3	-42.4	-53.5	-65.7	-62.8	-23.3	-37.8	-23.5	-45.4	-53.3	-28.4	-50.0
1993	-31.8	-61.9	-49.1	-73.2	-42.6	-44.6	-65.4	-27.9	-36.7	-57.7	-43.4	-55.4
84-93 MPE	-21.3	-37.0	-33.9	-56.3	-51.3	-19.6	-29.6	-10.3	-17.0	-46.4	-23.4	-43.3
84-93 MAPE	46.8	37.0	45.4	56.3	51.3	22.6	47.0	31.1	33.3	46.4	25.0	43.3
					RECENT DATA FORECASTS							
1984	-21.7	-4.1	47.4	-34.0	-27.7	105.7	355.7	196.4	80.2	-18.7	152.9	-2.5
1985	-29.6	83.7	2.9	-44.0	-49.1	141.0	227.6	34.8	92.4	-33.2	124.4	-19.6
1986	287.6	-0.7	3.7	-36.1	-15.7	93.1	59.1	23.5	28.5	14.3	56.0	23.0
1987	-55.9	9.8	68.9	-27.4	59.2	-3.7	98.1	248.4	14.6	-17.5	45.2	-6.6
1988	33.1	28.6	35.4	-28.5	51.9	68.4	181.0	177.0	-26.9	9.4	74.3	20.1
1989	-37.6	-33.5	0.9	-44.0	-24.3	4.4	-24.1	-2.3	287.7	-34.4	5.5	-29.7
1990	-47.5	-26.4	-55.7	-53.4	9.6	-4.6	0.5	-16.1	23.6	-46.7	-5.1	-41.3
1991	-25.6	-37.5	-52.4	-33.2	-50.2	-21.6	-53.4	-12.8	-35.4	-39.9	-30.3	-38.0
1992	-12.1	-15.6	-37.1	-54.8	-41.8	5.6	22.4	-23.5	-24.2	-38.9	-5.2	-34.4
1993	-4.5	-49.3	-39.7	-67.3	-33.2	-29.0	-35.8	-27.9	-22.1	-46.2	-29.4	-43.6
84-93 MPE	8.6	-4.5	-2.6	-42.3	-12.1	35.9	83.1	59.8	41.8	-25.2	38.8	-17.3
84-93 MAPE	55.5	28.9	34.4	42.3	36.3	47.7	105.8	76.3	63.6	29.9	52.8	25.9

[a] Percent error calculated as:
(forecast - actual total return) / actual total return x 100.

[b] Hindcasts 1984-91 were for Nuyakuk River, 1992-93 hindcasts were for total Nushagak River.

Appendix B.2. Annual percent errors, mean percent errors (MPE), and mean absolute percent errors (MAPE) for hindcasts of total sockeye salmon returns to Bristol Bay river systems, 1984-93, based on the Mixed Data method[a].

	Percent Errors[b]									
Year	Kvichak	Branch	Naknek	Egegik	Ugashik	Wood	Igushik	Nuyakuk/ Nushagak[c]	Togiak	Total
1984	-21.7	-4.1	47.4	-34.0	-27.7	-12.2	73.5	23.9	0.4	-16.2
1985	-29.6	83.7	2.9	-44.0	-49.1	5.1	-33.5	-4.6	-20.5	-30.8
1986	287.6	-0.7	3.7	-36.1	-15.7	-3.5	-36.2	-26.8	-4.4	7.6
1987	-55.9	9.8	68.9	-27.4	59.2	-35.0	-18.9	37.7	-24.0	-18.3
1988	33.1	28.6	35.4	-28.5	51.9	9.9	13.5	42.3	-56.0	7.6
1989	-37.6	-33.5	0.9	-44.0	-24.3	-24.6	-64.5	-37.0	81.0	-34.3
1990	-47.5	-26.4	-55.7	-53.4	9.6	-29.6	-51.1	-52.2	-11.9	-45.8
1991	-25.6	-37.5	-52.4	-33.2	-50.2	-38.0	-75.9	-34.8	-52.3	-41.8
1992	-12.1	-15.6	-37.1	-54.8	-41.8	-23.3	-37.8	-23.5	-45.4	-37.5
1993	-4.5	-49.3	-39.7	-67.3	-33.2	-44.6	-65.4	-27.9	-36.7	-45.8
84-93 MPE	8.6	-4.5	-2.6	-42.3	-12.1	-19.6	-29.6	-10.3	-17.0	-25.5
84-93 MAPE	55.5	28.9	34.4	42.3	36.3	22.6	47.0	26.3	33.3	28.6

[a] Recent Data (1978-92) used for Kvichak, Branch, Naknek, Egegik, and Ugashik River systems; All Data (1956-92) used for other river systems.

[b] Percent error calculated as: (forecast - actual total return) / actual total return x 100.

[c] Hindcasts 1984-91 were for Nuyakuk River, while the 1992-93 hindcast was for total Nushagak River.

APPENDIX C: UNADJUSTED RIVER SYSTEM FORECASTS

Appendix C.1. Forecasted returns of major age classes of sockeye salmon to the Kvichak River in 1994 based on linear regression models using spawner-recruit, sibling, and smolt data.

<u>Spawner-Recruit Data</u>

Age Class	Spawning Escapement (thousands)	Predicted Return (thousands)	Approximate Significance Level (%)	Sample Size
1.2	6,970	3,358	5.0	16
2.2	8,317	8,228	0.1	16
1.3	8,317	2,229	0.1	16
2.3	4,065	853	2.5	16
	Total	14,668		

<u>Sibling Data</u>

Age Class	Sibling Return in 1993 (thousands)	Predicted Return (thousands)	Approximate Significance Level (%)	Sample Size
1.2	8	3,927[a]	NS	10
2.2	117	15,563	0.1	13
1.3	2,129	1,185	1.0	15
2.3	4,328	681	1.0	15
	Total	21,356		

<u>Smolt Data</u>

Age Class	Smolt Production (thousands)	Predicted Return (thousands)	Approximate Significance Level (%)	Sample Size
1.2	18,172	1,532	5.0	16
2.2	61,317	5,290	0.1	16
1.3	87,187	1,566	5.0	15
2.3	34,266	587	10.0	15
	Total	8,975		

[a] Estimate not used; regression model not significant at 25% level ($P > 0.25$).

Appendix C.2. Forecasted returns of major age classes of sockeye salmon to the Branch River in 1994 based on linear regression models using spawner-recruit and sibling data.

Spawner-Recruit Data

Age Class	Spawning Escapement (thousands)	Predicted Return (thousands)	Approximate Significance Level (%)	Sample Size
1.2	169	211	5.0	16
2.2	197	44	25.0	15
1.3	197	167	2.5	16
2.3	195	11	25.0	16
	Total	433		

Sibling Data

Age Class	Sibling Return in 1993 (thousands)	Predicted Return (thousands)	Approximate Significance Level (%)	Sample Size
1.2	2	206	10.0	13
2.2	2	69[a]	NS	4
1.3	350	164[a]	NS	15
2.3	275	29	25.0	14
	Total	468		

[a] Estimate not used; regression model not significant at 25% level (P>0.25).

Appendix C.3. Forecasted returns of major age classes of sockeye salmon to the Naknek River in 1994 based on linear regression models using spawner-recruit and sibling data.

Spawner-Recruit Data

Age Class	Spawning Escapement (thousands)	Predicted Return (thousands)	Approximate Significance Level (%)	Sample Size
1.2	2,093	740	25.0	16
2.2	1,162	660	25.0	16
1.3	1,162	1,328	10.0	16
2.3	1,038	844	2.5	16
	Total	3,572		

Sibling Data

Age Class	Sibling Return in 1993 (thousands)	Predicted Return (thousands)	Approximate Significance Level (%)	Sample Size
1.2	0	[a]		
2.2	5	877[b]	NS	13
1.3	224	823	2.5	15
2.3	509	810	1.0	15
	Total	2,510		

[a] Estimate not made; no age-1.1 sockeye salmon returned to Naknek River in 1993.

[b] Estimate not used; regression model not significant at 25% level (P>0.25).

Appendix C.4. Forecasted returns of major age classes of sockeye salmon to the Egegik River in 1994 based on linear regression models using spawner-recruit, sibling, and smolt data.

Spawner-Recruit Data

Age Class	Spawning Escapement (thousands)	Predicted Return (thousands)	Approximate Significance Level (%)	Sample Size
1.2	2,192	217	2.5	16
2.2	1,612	6,899	2.5	16
1.3	1,612	2,116[a]	NS	16
2.3	1,613	2,599	25.0	16
	Total	11,831		

Sibling Data

Age Class	Sibling Return in 1993 (thousands)	Predicted Return (thousands)	Approximate Significance Level (%)	Sample Size
1.2	0	[b]		
2.2	34	4,557	1.0	15
1.3	601	1,091	0.1	15
2.3	11,037	4,403	5.0	15
	Total	10,051		

Smolt Data

Age Class	Smolt Production (thousands)	Predicted Return (thousands)	Approximate Significance Level (%)	Sample Size
1.2	6,048	623	2.5	10
2.2	17,338	3,323	1.0	10
1.3	4,519	1,238	1.0	9
2.3	89,162	11,105	10.0	9
	Total	16,289		

[a] Estimate not used; regression model not significant at the 25% leve (P>0.25).

[b] Estimate not made; no age-1.1 sockeye salmon returned to Egegik River in 1993.

Appendix C.5. Forecasted returns of major age classes of sockeye salmon to the Ugashik River in 1994 based on linear regression models using spawner-recruit, sibling, and smolt data.

Spawner-Recruit Data

Age Class	Spawning Escapement (thousands)	Predicted Return (thousands)	Approximate Significance Level (%)	Sample Size
1.2	750	656	1.0	16
2.2	1,713	2,287	1.0	16
1.3	1,713	1,801	0.5	16
2.3	654	497	0.1	16
	Total	5,241		

Sibling Data

Age Class	Sibling Return in 1993 (thousands)	Predicted Return (thousands)	Approximate Significance Level (%)	Sample Size
1.2	1	781	5.0	12
2.2	14	1,609	10.0	14
1.3	703	856	0.1	15
2.3	2,186	783	0.1	15
	Total	4,029		

Smolt Data

Age Class	Smolt Production (thousands)	Predicted Return (thousands)	Approximate Significance Level (%)	Sample Size
1.2	[a]			
2.2	[a]			
1.3	26,056	879	25.0	8
2.3	47,713	1,093[b]	NS	8
	Total	1,972		

[a] Estimate not made; smolt were not counted in Ugashik River in 1992.

[b] Estimate not used; regression model not significant at 25% level (P>0.25).

Appendix C.6. Forecasted returns of major age classes of sockeye salmon to the Wood River in 1994 based on linear regression models using spawner-recruit and sibling data.

Spawner-Recruit Data

Age Class	Spawning Escapement (thousands)	Predicted Return (thousands)	Approximate Significance Level (%)	Sample Size
1.2	1,069	932	0.1	34
2.2	1,186	101	10.0	33
1.3	1,186	1,022	0.1	33
2.3	867	55	10.0	30
	Total	2,110		

Sibling Data

Age Class	Sibling Return in 1993 (thousands)	Predicted Return (thousands)	Approximate Significance Level (%)	Sample Size
1.2	1	623	1.0	24
2.2	0	[a]		
1.3	2,300	1,097	2.5	37
2.3	91	52	0.1	35
	Total	1,772		

[a] Estimate not made; no age-2.1 sockeye salmon returned to Wood River in 1993.

Appendix C.7. Forecasted returns of major age classes of sockeye salmon to the Igushik River in 1994 based on linear regression models using spawner-recruit and sibling data.

Spawner-Recruit Data

Age Class	Spawning Escapement (thousands)	Predicted Return (thousands)	Approximate Significance Level (%)	Sample Size
1.2	366	123	1.0	34
2.2	462	45	5.0	33
1.3	462	566	0.1	33
2.3	170	30	0.1	32
	Total	764		

Sibling Data

Age Class	Sibling Return in 1993 (thousands)	Predicted Return (thousands)	Approximate Significance Level (%)	Sample Size
1.2	0	[a]		
2.2	0	[a]		
1.3	509	656	1.0	37
2.3	41	38	0.1	37
	Total	694		

[a] Estimates not made; no age-1.1 or age-2.1 sockeye salmon returned to Igushik River in 1993.

Appendix C.8. Forecasted returns of major age classes of sockeye salmon to the Nushagak River in 1994 based on linear regression models using spawner-recruit and sibling data.

Spawner-Recruit Data

Age Class	Spawning Escapement (thousands)	Predicted Return (thousands)	Approximate Significance Level (%)	Sample Size
0.2	495	43	2.5	12
1.2	675	131	2.5	12
2.2	513	6[a]	NS	11
0.3	675	512	2.5	12
1.3	513	831	0.1	12
2.3	483	11[a]	NS	12
0.4	513	61	10.0	12
	Total	1,595		

Sibling Data

Age Class	Sibling Return in 1993 (thousands)	Predicted Return (thousands)	Approximate Significance Level (%)	Sample Size
0.2	0	[b]		
1.2	0	[b]		
2.2	0	[b]		
0.3	53	523	0.1	11
1.3	125	756	5.0	11
2.3	12	14	10.0	10
0.4	489	69	2.5	11
	Total	1,362		

[a] Estimate not used; regression model not significant at 25% level (P>0.25).

[b] Estimates not made; no age-0.1, -1.1, or -2.1 sockeye salmon returned to Nushagak River in 1993.

Appendix Table C.9. Forecasted returns of major age classes of sockeye salmon to the Togiak River in 1994 based on linear regression models using spawner-recruit and sibling data.

Spawner-Recruit Data

Age Class	Spawning Escapement (thousands)	Predicted Return (thousands)	Approximate Significance Level (%)	Sample Size
1.2	189	110	1.0	34
2.2	104	23	1.0	33
1.3	104	193	0.5	33
2.3	309	28	0.1	32
	Total	354		

Sibling Data

Age Class	Sibling Return in 1993 (thousands)	Predicted Return (thousands)	Approximate Significance Level (%)	Sample Size
1.2	0	[a]		
2.2	0	[a]		
1.3	132	279	0.5	37
2.3	33	30	0.5	37
	Total	309		

[a] Estimate not made; no age-1.1 or age-2.1 sockeye salmon returned to Togiak River in 1993.